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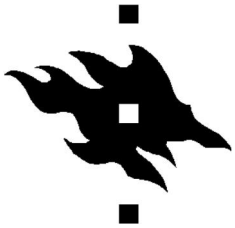

Viewpoints of Residential Multi-Story Construction Industry's Productivity, Environmental Regulations and Future in Finland

Master's Thesis
Forest Economics and Marketing
Faculty of Agriculture and Forestry

Juho Aleksi Aaltonen
May 2019

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Tiivistelmä — Referat — Abstract

Growing concern on climate change has provided impetus for developing and implementing sustainable solutions in various industries. For instance, the theme of bioeconomy has increasingly gained interest in the 2000s. Other megatrends such as population growth and urbanization further highlight the importance of finding and implementing sustainable solutions to various industries, or as in this connection, the examination of the residential multi-story construction (MC) industry. More specifically, viewpoints regarding the industry's productivity, environmental regulations and future trends regarding both MC and residential wooden multi-story construction (WMC) were emphasized.

This study was conducted applying qualitative research methods. Semi-structured interviews were held in 2018 for 10 construction company executives, managers or people with an equivalent status mainly in areas related to procurement and production. The selected sampling strategy was purposeful sampling. The main criterion in the selection process was that the companies contacted did not have prior experience in WMC, as they were not seen being overly represented in previous literature especially in the context of WMC.

Based on the results, the majority of experts perceived the productivity development in the construction industry similar as previous studies have shown. That is, productivity development has been slow compared to other industries. Some of the expressed solutions considered moving increasingly more toward prefabricated solutions and minimizing on-site construction, and the further development of technologies such as building information models (BIMs). However, the current zoning policies were seen to inhibit some of the potential, as they do not permit incorporating more repetitive production methods. The adoption rate of digital solutions were mentioned as an opportunity for productivity development, and the role of digitalization was seen to enhance productivity.

Regarding the theme of environmental regulations, no additional or special metrics were brought up, as the current policies already demand extensive documentation. The emphasis in discussion was more inclined toward operational energy use instead of embodied energy. For example, investigating opportunities for implementing geothermal heat or solar panels were mentioned. Investors were seen to demand increasingly environmental certifications (e.g., BREEAM & LEED) in real-estate investments, however, consumer demand for this was not specifically identified.

Regarding future trends in MC, prefabrication was mentioned the most often. In addition, digitalization and robotics were seen to have a larger role in future. The effects of urbanization to the Finnish housing market and to the consumers raised questions. As the results imply that the prefabrication rate will increase in the future, this in turn could possess a potential for WMC especially in off-site modular construction. However, it would seem that e.g. clear cost-advantages should be achieved to raise grater interest of construction companies. The results found similar implications of other studies where producing cost-advantages and developing standardization was emphasized. The market share of WMC in future was seen to either stay at the current levels or to increase. Notably, none of the experts saw that the market share of WMC would decrease toward 2030.

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Residential Multi-Story Construction, Wooden Multi-Story Construction, environmental regulation, future trends, productivity

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Näkökulmia suomalaisen asuinkerrostalorakentamisen tuottavuuteen, ympäristösäädöksiin ja tulevaisuuden trendeihin.

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Tiivistelmä — Referat — Abstract

Kasvava huoli ilmastonmuutoksesta on antanut sysäyksen kestävämpien ratkaisujen kehittämiselle ja toteuttamiselle eri toimialoilla. Biotalouden teema on eräs esimerkki, joka on kasvattanut kiinnostusta 2000-luvun ensikymmenellä. Myös muut nk. megatrendit, kuten väestönkasvu ja kaupungistuminen, korostavat uusien kestävien ratkaisujen löytämistä ja käyttöönoton tärkeyttä. Tämän tutkimuksen keskipisteenä on asuinkerrostalorakentamisen liiketoiminta, jota tarkastellaan keskittyen erityisesti toimialan tuottavuuden, ympäristösäädöksien ja tulevaisuuden trendien näkökulmista.

Tutkimus toteutettiin kvalitatiivisia tutkimusmenetelmiä käyttäen. Kymmenen (10) puolistrukturoitua haastattelua toteutettiin vuonna 2018 rakennusyhtiöiden johtajille tai vastaavan aseman omaaville asiantuntijoille, joilla on kattava kokemus alalta. Käytetty otantamenetelmä oli harkintaan perustuva, jossa pääkriteerinä oli valita yhtiöitä, jotka eivät olleet rakentaneet puukerrostaloa yhteydenottohetkellä. Peruste valinnalle oli se, että aiemmissa tutkimuksissa tämänkaltainen kohderyhmä ei näytä olevan edustettuna, eritoten puukerrostalorakentamiseen liittyvissä tutkimuksissa.

Tulosten perusteella valtaosa asiantuntijoista pitivät rakennusalan tuottavuuden kehitystä samankaltaisena kuin aiemmat tutkimukset ovat osoittaneet. Toisin sanoen, tuottavuuskehitys on ollut hidasta verrattuna muihin toimialoihin. Siirtyminen yhä enemmän esivalmistettujen ratkaisujen käyttöön, työmaarakentamisen vähentäminen sekä teknologioiden, kuten rakennustietomallien (BIM) kehittäminen olivat eräitä mainittuja ratkaisuja tuottavuuden parantamiseksi.

Ympäristösäädösten aihepiirin osalta ei esiin tullut ylimääräisiä tai erityisiä mittareita, koska nykyiset käytännöt edellyttävät jo esim. laajaa dokumentaatiota. Pääpaino tämän teeman osalta keskittyi ennemmin löytämään ratkaisuja liittyen käytön ajan energiatuotantoon kuin elinkaaren alkupään toimiin. Esimerkiksi maalämmön ja aurinkopaneelien hyödyntämisen mahdollisuuksia tutkittiin ja hyödynnettiin jo nykyisellääkin. Sijoittajien nähtiin kysyvän yhä enemmän ympäristösertifikaatteja (esim. BREEAM & LEED) kiinteistösijoituksissaan, mutta erityistä kuluttajakysyntää ei identifioitu.

Tulevaisuuden trendejä koskien, (teollinen) esivalmistus mainittiin useimmiten. Tämän lisäksi digitalisaation ja robotiikan nähtiin olevan suuremmassa roolissa tulevaisuudessa. Kaupungistumisen vaikutukset Suomen asuntomarkkinaan ja sen vaikutukset kuluttajiin herättivät myös kysymyksiä. Toisin sanoen, arvioitu esivalmistusasteen kasvu voi olla myös potentiaalinen ajuri puukerrostalorakentamisessa, varsinkin tehdasmaisessa tilaelementtirakentamisessa. Näyttäisi kuitenkin siltä, että esimerkiksi selkeitä kustannusetuja tulisi saada, jotta suurempi kiinnostus löytyisi. Tämä tutkimus löysi samankaltaisia tuloksia verrattuna aiempaan kirjallisuuteen, jossa kustannuskilpailukyky ja standardoimisen edelleen kehittäminen ovat olleet keskiössä. Puukerrostalojen markkinaosuuden arvioitiin joko pysyvän nykyisellään tai kasvavan. Huomioitavaa oli se, että kukaan asiantuntijoista ei arvioinut markkinaosuuden laskevan vuoteen 2030 mennessä.

Avainsanat — Nyckelord — Keywords
Asuinkerrostalorakentaminen, puukerrostalorakentaminen, ympäristösäädökset, tulevaisuuden trendit, tuottavuus

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1 Introduction

1.1 Background

The increasing awareness on climate change together with various governmental actions, business innovations and technological advancements have enabled e.g. to increase material and energy efficiency and finding other viable or new options in the business environment. Regarding the terms commonly used in areas of finding and implementing more environmentally sustainable options, the concept of *bioeconomy* has gained popularity in discourse since 2005 (Ollikainen, 2014). Although bioeconomy can have different meanings depending on the context at hand (Bugge, Hansen, & Klitkou, 2016), one way of defining the term is: *"The production of renewable biological resources and the conversion of these resources and waste streams into value added products, such as food, feed, bio-based products and bioenergy"* (European Commission [EC], 2012, p. 3).

Given that wood is a renewable material and assuming that sustainability criteria are met when conducting forest management activities, there are other industries where the use of forest industry products should, at a minimum, be considered. One example of such inspection is the possibilities in the construction industry, and more specifically in the context of this study, in the residential multi-story construction (MC) sector. At least one of the catalysts for finding alternatives for the business-as-usual (BAU) practices are the efforts to reduce greenhouse gas (GHG) emissions and act toward sustainable development goals. The construction industry is one of the key sectors where efforts to decrease emissions are possible as it generates together with the use of buildings for approximately 35% of GHG emissions in the European Union (EU) (EC, 2011). Furthermore, 42% of final energy consumption and 50% of all extracted material can be directed at the sector (EC, 2011).

In Finland, buildings are divided into four fire classes: P0, P1, P2 and P3. Three to eight story wooden buildings are classified as fire class P2 and two-story houses as fire class P3. In this thesis, a wooden-framed multi-story construction (WMC) is defined as over a two-story residential building with a fire resistance class of P2. Building products are classified on the grounds of their reaction to fire ignition, production of smoke and the amount of flaming droplets. Further information and detailed explanation on the

classification can be observed in Annex 1. (The National Building Code of Finland, 2002, 2017.)

In order to finish a P2 classified WMC, a few prerequisites must be fulfilled. Over two story wooden-framed apartment buildings must be equipped with automatic fire extinguishing equipment in Finland, which is not case in some neighboring countries. In addition, 3–4 story buildings and 5–8 story buildings have different standard requirements for extinguishing systems. The standards become stricter when more stories are built. Moreover, building height, insulations, fire resistance capacity and inner and outer cladding are among many additional prerequisites that need to be obeyed. (Tolppanen, Karjalainen, Lahtela, & Viljakainen, 2013, p. 137.)

On paper, the implementation of WMC projects were not possible before the update of the National Building Code's fire safety requirements (E1) in 1.9.1997, as the previous regulation from 1981 prohibited the use of wood in over 2-story or over 7-meter-high buildings as a load bearing structure and as a main material in façades. In practice, however, some experimental buildings were built with special permission such as in Viikki, Helsinki (see e.g., PUU, 1997). The National Building Code of 1997 permitted the construction of 3–4 story P2 class wooden framed buildings with a wooden façade with a maximum height of 14 meters on account of the provisions. After 1997, the National Building Code regulations concerning fire safety in residential buildings (E1) have been revised five times: in 2002 with two minor changes in 2008, changes in 2011 and the current, gradually updated from 2013-2017, which came into effect 1.1.2018. Arguably, the most notable changes in the building codes between 1997 and 2018 concerning P2 class buildings are the height and story limits. For instance, in 1997, the highest P2 class residential or office building was limited to 4 stories and 14 meters up until 2011 when the limits broadened to 8 stories and 26 meters. As of 2018, the limits are 8 stories and 28 meters. In the newest building code regarding P2 class buildings, the inclusion of nursing institutions, accommodation buildings (e.g., hotels), commercial buildings and recreational buildings were added besides residential buildings and office premises (The Ministry of the Environment, 2017). Additionally, the new building code enables leaving wooden materials exposed in ceilings and walls to an extent of 20% if particular requirements are met (The National Building Code, 2017) as it was seen to broaden architectural solutions without compromising fire safety levels of the past (The

Ministry of the Environment, 2017). It is worth noting that the fire class P0 is also a new addition to the building code. According to section 4, the fire class P0 needs to be used in instances where a building is designed by expected fire development (The National Building Code, 2017).

Thus, changes in fire regulations for the past of 20 years have become more permissive toward WMC in terms of building height and stories. Additionally, when designing buildings by the expected fire development (P0), it is possible to build e.g. higher than the standard ramifications e.g. of P2 class would allow. Therefore, incremental concessions from the regulatory side regarding WMC is evident. However, according to the results of Hurmekoski, Pykäläinen and Hetemäki (2018), the Finnish national building codes in general, and especially the fire codes, are seen as rather strict by industry stakeholders. Interestingly, Ijäs (2013, pp. 166–168) found that developers and structural engineers saw that the largest individual barrier to WMC was appreciation and attitude, lack of knowledge and information, technical aspects and then followed by an equal weight of cost factors and regulations.

In Finland, the first WMC projects were completed in mid-1990s. Karjalainen (2002, p. 20) argues that among other significant changes in society, forest industry and construction industry, the primary reason for the development of WMC was when Finland became a member state of the EU. Becoming a member changed the fire codes in way that permitted building 3–4 story residential and office buildings (Karjalainen, 2002, p. 20). Despite the first appearance of WMC over 20 years ago and possessing vast forest resources, technological capabilities and traditions of utilizing wood in various forms, it could be stated that the full potential has not been reached in Finland. For example, WMC is considered to act at a niche-level still even recently (Toppinen, Sauru, Pätäri, Lähtinen, & Tuppura, 2018a). The construction industry can be characterized as path-dependent (Hurmekoski, Hetemäki & Linden, 2015a; Mahapatra & Gustavsson, 2008), which can be seen when focusing on cost-effectiveness and risk reduction over longer periods (Jones, Stegemann, Sykes, & Winslow, 2016). Moreover, cultural and cognitive rationale affecting the adoption rate of WMC can be identified (Hemström, Gustavsson, & Mahapatra, 2017a; Hemström, Mahapatra, & Gustavsson, 2017b) as concrete-based construction has become the standard in the late 1950s and early 1960s (Karjalainen, 2002, pp. 61–62). Giesekam, Barrett, Taylor and Owen (2014) identified barriers for

adopting alternative materials, technologies and practices through an exhaustive systematic review, which they categorized under four headings: institutional and habitual, economic, technical and performance-related and knowledge and perceptions. Thus, the spectrum of barriers can be seen to include both measurable and unmeasurable factors.

Almost 59% of residential buildings today were built from 1970 or after and from 1990, the total number of buildings have increased by 30% by the end of 2016. At the end of 2016, the whole building stock (excluding summer cottages, agricultural and other utility buildings) was 1.5 million units, from which residential buildings accounted for 1.3 million units, or approximately 85.3%. Furthermore, the number of detached houses have a major share of residential buildings (76%) followed by row and linked houses (5.3%) and multi-story buildings (4%). (Official Statistics of Finland [OSF], 2017a.) Although the unit amount of multi-story buildings from all residential buildings is relatively low, 35.7% of the Finnish population lived in blocks of flats at the end of 2016 (OSF, 2017b). Moreover, commenced multi-story building projects have risen in the past few years (see Figure 1.1). Partly the reasons for this trend are urbanization and improved confidence in the economy since the financial crisis of 2008. Additionally, according to Puuinfo (2017), the growth of multi-story construction has been influenced by the appearance of housing funds and investors and the low interest rates accompanied by new financing methods (e.g., housing company debt) have affected the consumer demand increasingly as well.

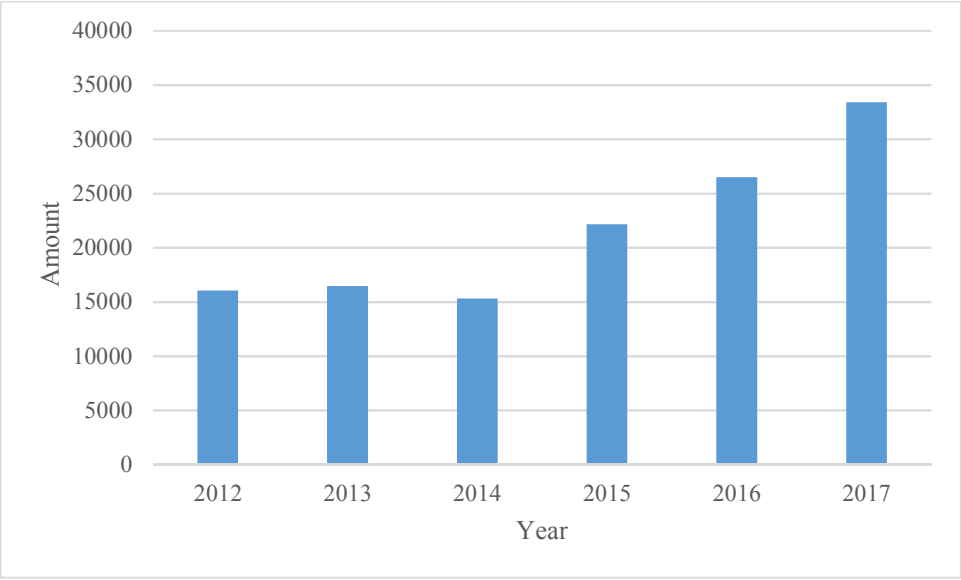


Figure 1.1. Commenced multi-story building projects 2012–2017. Data from OSF, Building and dwelling production (2018a).

Despite the fact that Finland holds large forest resources and a history of wood utilization, the amount of WMC is relatively low. According to Puuinfo (2019), there were 77 wooden residential multi-story buildings, which can be specified as over two-story buildings with a wooden structural frame and mainly a wooden façade in March 2019. Furthermore, there are 2,098 dwellings in these buildings (Puuinfo, 2019). In order to understand the scale of the current situation, it is important to examine and how it compares with the total building stock.

During the years 1996–2012, 13 areas with block of flats comprising of 37 buildings and 649 dwellings were built (Puuinfo, 2019). In that period, approximately 33% of dwellings were built, compared to the total WMC building stock in December 2018. This indicates that growth in the total building stock has especially been prevalent from 2013 onwards.

Figure 1.2 depicts the amount of timber used in frames and cladding in different buildings in 2012. The lowest amount of wood used in the structural frame and cladding was in multi-story buildings followed by industrial and warehouse buildings and public buildings. However, the largest growth potential compared with the market size lies in public- and business buildings, industry and warehouses and in apartment buildings just after detached houses. Therefore, the amount of timber in frames and claddings could theoretically be increased by a large margin.

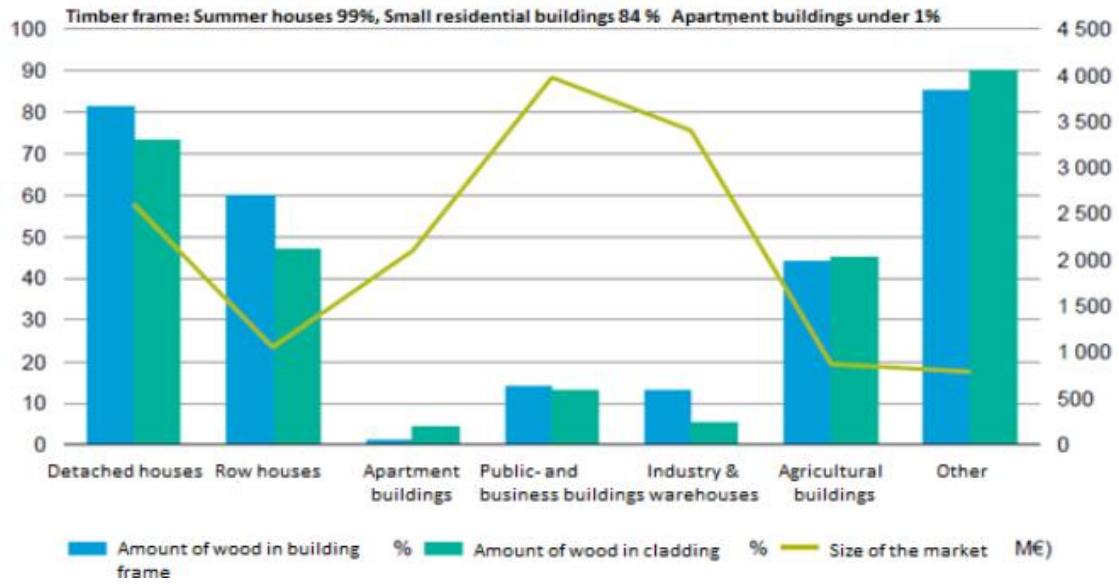


Figure 1.2. The growth possibilities for wood in apartment buildings, public and commercial buildings and industry buildings. Adapted from The Ministry of Employment and the Economy (2012).

According to a situation assessment of November 2018 (Ministry of the Environment & Puuinfo, 2018), there are future projects which are either certain, probable or possible. The assessment considers all over 2-story WMC projects and other large-scale public building projects in Finland. At that time, there were 10 certain, 28 probable and 13 possible projects, from which some are WMC neighborhoods rather than a singular building. Based on the calculations, the number of apartments on the way were approximately 1,100, 5,240 and 3,670, respectively (Ministry of the Environment & Puuinfo, 2018). As presented in Figure 1.1, the commenced building project have seen a relatively substantial increase from 2015. However, it has not realized in a larger share of WMC. Still, in the current concrete-driven building practice the share of WMC has kept up in the pace and managed to hold its market share of approximately 4% in 2017, compared with apartment amounts and cubic meters (Puuinfo, 2018). In 2017, an increase was seen in issued building permits as permits for WMCs increased by 9% when compared to the total volume (m^3). Additionally, increases were apparent in medical care institutions (23%) and educational buildings (11%) while the issued total building permit volumes decreased by 9% and 19% in these sectors respectively. (Puuinfo 2018.)

Building a WMC can be done using different methods and products. Engineered wood products (EWPs), such as cross-laminated timber (CLT), laminated veneer lumber (LVL) and glued laminated timber (Glulam) are commonly used as they fulfill the structural and

technical requirements needed for these types of buildings. The various technical properties, such as fire, acoustical, seismic performance of EWPs have been studied (e.g., Gagnon, Pirvu, & FPInnovations, 2011; Laguarda Mallo & Espinoza, 2015) and potential of using them from a strategical viewpoint (e.g., SWOT-analysis) have been conducted (Nykänen et al., 2017; Vatanen, Sirkka, Pirttinen, & Ahoranta, 2017). Many of the results show that they have technical capabilities and possess advantages in some areas compared to the common building materials thus being a viable option in multi-story construction. The properties needed and the implementation validity of the plans determine the best solution for a specific product in question.

Furthermore, there are different structural methods for building a WMC project. According to Puuinfo (2011), the most commonly used structural method in WMC is based on load-bearing walls using a platform frame construction method, where the frame can be built by using either timber-framed structures or massive wood panels. In the platform frame method each floor is built individually providing a platform for building on top of the previous one.

Modular solutions enable working in controlled conditions limiting some of the unfavorable effects on costs, schedule and quality (Moghadam, Alwisy, & Al-Hussein, 2012). Shifting to using modules could change the working environment from on-site to off-site even as much as 90% (Johnsson & Meiling, 2009). Furthermore, combining the information from building information models (BIMs) with lean principles in modular construction has showed positive results e.g. in time and waste reduction (Moghadam et al., 2012) and using BIMs are essential in WMC design (Ruuska & Häkkinen, 2016). According to the findings of Ruuska & Häkkinen (2016) the construction phase potential in timber solutions are not yet fully realized in areas of cost and time, however, operating indoors were seen to improve quality. Some construction companies have taken more control of the chain i.e. implementing vertical integration by investing into modular systems in Finland (e.g., Sisco Oy).

1.2 Purpose of the study

On the basis of what has been stated above, combining the themes of bioeconomy and construction industry can be therefore seen as a subject of interest. Moreover, previous studies regarding material selection have mainly focused on viewpoints from structural

engineers, architects and actors in the forest industry rather than other key players in the construction industry value chain (see e.g., Gosselin, Blanchet, Lehoux, & Cimon, 2017; Hemström et al., 2017a). In addition, when multiple stakeholders were studied, a clear distinction in answers has remained partly undistinguished (Hemström et al., 2017a). In other words, it seems that less focus has been addressed in literature for stakeholders outside the wood products industry compared to the views from the industry itself. Therefore, the focus of this study is to view the current residential multi-story construction (MC) business environment and potential trends toward 2030 from the viewpoint of construction industry experts. More specifically, the aim is to examine the current undertones of residential multi-story construction (MC) and the role of wooden-framed multi-story construction (WMC) with insights from construction company managers and executives. The research questions are as follows:

RQ1: How is the current multi-story construction productivity seen, and what are the ways of improving it?

RQ2: What are the perceptions of construction industry experts toward the current and future environmental regulatory policies and how are these issues addressed?

RQ3: What are the future trends in multi-story construction toward the year 2030?

RQ4: How is the role of wooden multi-story construction seen toward the year 2030?

2 Contextual Background

2.1 Environmental Regulations affecting WMC

2.1.1 Global context

Over the past decades, an increasing attention has been addressed to issues related to climate change. Reducing the levels of anthropogenic i.e. human-emitted GHG levels, such as carbon dioxide (CO_2), has been subject to various global and national climate change mitigation policies. Possibly the most well-known global policy is the United Nations Framework Convention on Climate Change (UNFCCC) of 1992, which was followed by the Kyoto Protocol of 1997 and the Paris Agreement in 2015. Article 2 of the 1992 treaty expresses the ultimate objective as *"stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system."* (UNFCCC, 1992, p. 9). The Paris Agreement set a long-term goal of keeping global temperature rise below 2 degrees Celsius, although preferably to 1.5 degrees Celsius, above pre-industrial levels (UNFCCC, 2015).

According to Intergovernmental Panel on Climate Change (IPCC), total GHG emissions have increased from 1970 to 2010 with a larger proportion toward the end of the reference period (IPCC, 2014). It was estimated that during the same period, 78% of the total GHG emission increase were CO_2 emissions from fossil fuel combustion and industrial processes (IPCC, 2014). Furthermore, from a time period of 260 years spanning from 1750 to 2010, approximately half of the cumulative anthropogenic CO_2 emissions have occurred in the last 40 years (IPCC, 2014). To limit warming to 1.5 degrees Celsius, global net-emissions should decrease by 45% from 2010 levels by 2030 and reaching net-zero emissions around 2050 (IPCC, 2018). Additionally, even the difference between 1.5 and 2 degrees Celsius has varying levels of added risks to natural, managed and human systems e.g. terrestrial ecosystems, crop yields and marine ecosystems (IPCC, 2018). Thus, drastic and immediate changes should be commenced immediately for reaching the estimated requirements of 2030.

Consumption of energy and sources of energy are evidently in key roles when examining climate impact. However, other aspects, such as material selection, should not be overlooked. When delving deeper into the material production and their accounted CO_2

emissions, the manufacturing of cement is estimated to be 4–8% of total global CO_2 emissions (Tolppanen et al., 2013, p. 127). Cement is a binding agent for concrete, which is the most consumed man-made material in the world (World Business Council for Sustainable Development [WBCSD] & International Energy Agency [IEA], 2018). Jointly with the production of steel, their industries accounted a global CO_2 impact of 15% in 2012 (van Ruijven et al., 2016). In contrast, wood has natural CO_2 sequestering properties as one cubic meter of wood stores approximately one ton of CO_2 (Tolppanen et al., 2013). In the case of concrete, most of the CO_2 emissions are a result of clinker production and are dependent on the fuel used to produce the energy needed in the manufacturing process. Furthermore, determining the clinker-to-cement ratio is important when estimating emissions. Depending on the different variables, a range in 0.65 to 0.92 kg of CO_2 per kg of cement is produced. (Moya, Pardo, & Mercier, 2010.) This is not to say that no progress or attempts toward lowering GHG emission have been made in the concrete industry. For example, an outlined technology roadmap for low-carbon transition in the cement industry estimated that the industry could reduce emission by 18% toward 2050 (WBCSD & IEA, 2009). In addition, low-carbon cements and Carbon Capture and Storage (CSS) technologies have been developed, however, governmental actions and financial support were among some propositions for further development. Nonetheless, there are challenges and trade-offs in adopting these newer solutions. (WBCSD & IEA, 2009.)

Efforts to combat climate change have been addressed at a global, international and national level. For instance, the EU has addressed these issues through various initiatives considering e.g. resource efficiency and circular economy (EC, 2011, 2015). Environmental impacts caused by nutrition, mobility and housing sectors account approximately for 70–80% of all environmental impacts in industrialized countries (EC, 2011). According to United Nations Environment Programme [UNEP] and IEA (2017), buildings and construction account nearly 40% of energy related CO_2 emissions and more than 35% of global final energy use in 2016. More specifically, 30% of the global total final energy use of building sector and nearly 6% of the global final energy use can be accounted to building construction and production of cement and steel. The reported levels in 2007 of buildings in the EU in terms of final energy consumption and production of all GHGs were 42% and 35%, respectively (EU, 2007).

2.1.2 EU-level initiatives

The financial crisis of 2008 and the subsequent economic effects influenced the European Commission to put forward a "Europe 2020"-strategy in 2010. The strategy highlighted the increasing megatrends of globalization, ageing population and resource scarcity. Furthermore, to reach the strategic objectives for smart, sustainable and inclusive growth, seven flagship initiatives were generated. One of these initiatives, i.e. "Resource efficient Europe", strives for a less carbon-intensive economy with an increase of renewable energy sources and resource efficiency. (EC, 2010.) One of the goals mentioned in the initiative is the previously set EU's 20-20-20 goal, where the aim is to reduce GHG emissions by 20% compared to 1990 levels, increase energy efficiency by 20% and obtain 20% of energy from renewable sources by 2020. Later on, goals have been made for 2030 and 2050. For instance, the goals for 2030 are more ambitious as the respective targets are 40%, 27% and 27% (EC, 2014).

Among a variety of environmental aspects, the roadmap to a resource efficient Europe emphasizes the need for strengthening resource and energy efficiency policies in the construction sector. Additionally, rather than concentrating solely on the initial costs of buildings, more focus toward the life-time costs of buildings was seen preferable. (EC, 2011.)

Another mentionable initiative is Level(s), which aims to improve the sustainability of buildings with a more uniform EU-level measurement framework considering the full lifecycle. The Level(s) framework is voluntary and focuses on six main objectives, namely GHG emissions, resource efficiency, water use, health and comfort, resilience and adaptation to climate change, and cost and value. (Dodd et al., 2017.) Building certification is another example of voluntary efforts for tracking the environmental performance of buildings. On the commercial building side in Europe, BREEAM certified buildings hold approximately an 80% market share certified buildings. Other more well-known certification systems include LEED, HQE and DGNB. However, according to one estimate the total share of certified residential buildings was in the range of 0.32% in 2013. (Herczeg et al., 2014.)

Ultimately, implementing these strategies and reaching targets is a national matter. The next paragraph considers some of the initiatives in Finland affecting the construction industry.

2.1.3 Initiatives in Finland

As briefly described previously of the global and EU-level actions for mitigating the effects of climate change, the Finnish government has its own initiatives for these issues. In the context related to wood construction, the national government has been active in showing interest through various campaigns and medium-term plans since the early 1990s (Karjalainen, 2002, pp. 38–44). Some of the more recent, post 2010 key strategies include the National Forest Strategy (MSO) of 2011, Finnish Bioeconomy Strategy of 2014 and the National Wood Building Programme of 2016 among others. For instance, the Finnish Bioeconomy Strategy suggests that bioeconomy would provide the next leap in the economy after subsistence economy and fossil economy (Bioeconomy, 2014). Moreover, the economic growth and employment is aimed to be achieved with high-value added products without compromising natural ecosystems and e.g. timber usage in WMC is considered as having one of the most potential (Bioeconomy, 2014).

The Ministry of Environment had made a roadmap for low-carbon building and building materials. As the regulations for a more energy efficient building has increased, and if emissions in energy production decrease, the proportional role of the building material emissions increase and becomes increasingly a subject of focus. France, Belgium and the Netherlands have transited for governmental steering norms regarding building material emissions with a varying degree, which means that Finland is not the only one with these attempts. (Bionova, 2017.) Figure 2.1 represents the roadmap, where the starting point is marked from 2017 with preparations followed by voluntary piloting phase and an ending point in 2025, where legally binding values for carbon footprint affecting the life cycle to all building types are meant to become mandatory. As a side note, this figure was showed in the interview of this study, and general comments and emphasis on financial steering was asked.

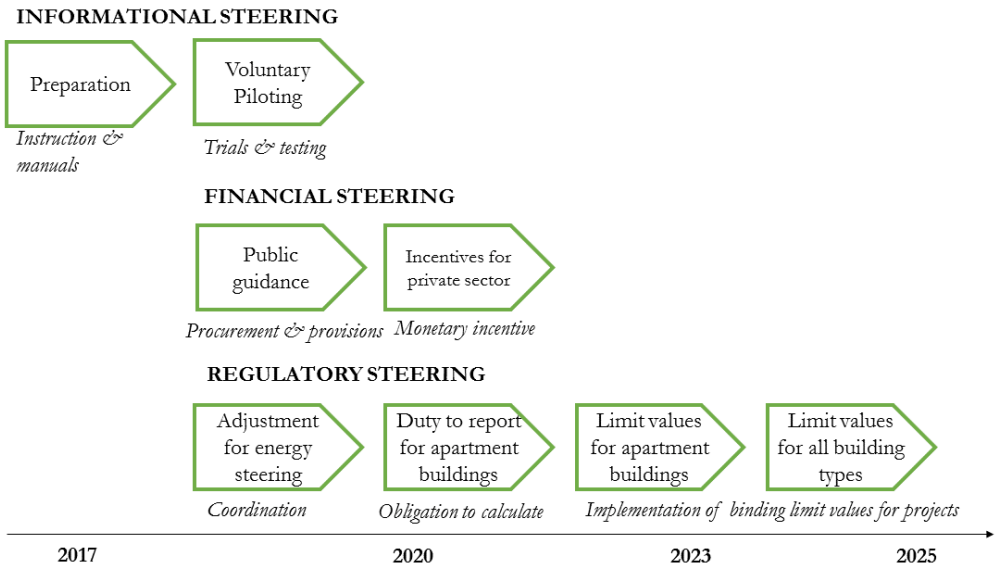


Figure 2.1. Translated roadmap for steering the development phases for low-carbon building. Adapted from Bionova, (2017, p. 40).

Another ongoing governmental programme is The National Wood Building Programme, which aims to support the Finnish Bioeconomy Strategy for in increasing the use of wood in construction and consequently increasing the carbon storage. In addition to its five focus areas, the programme aims to enhance the export possibilities for the Finnish wood products industry. (The Ministry of the Environment, 2018.)

In conclusion, it could be said that that the Finnish government has shown interest and has took action in finding ways to incorporate sustainable choices in accordance with global and the EU's goals through roadmaps and guides.

2.2 Stagnant productivity

2.2.1 Productivity development

Themes related to construction industry's productivity has been a reoccurring theme in media (Herrala, 2018; Lohilahti & Mölsä, 2017) and academia (Koskenvesa, Koskela, Tolonen, & Sahlsted, 2010) in Finland. However, it is a global dilemma as well (Bughin et al., 2017).

Bughin et al. (2017) examined productivity of the global construction industry and identified ten root causes for the acknowledged low rates of productivity. In addition, the report identified seven areas where a potential cumulative impact on productivity could be enhanced between 48%–60%. Figure 2.2 shows the rather poor development in productivity in construction compared to manufacturing and the total economy in terms of gross-value added per hour worked between 1995 and 2014 based on a sample of 41 countries that together cover almost completely the global GDP.

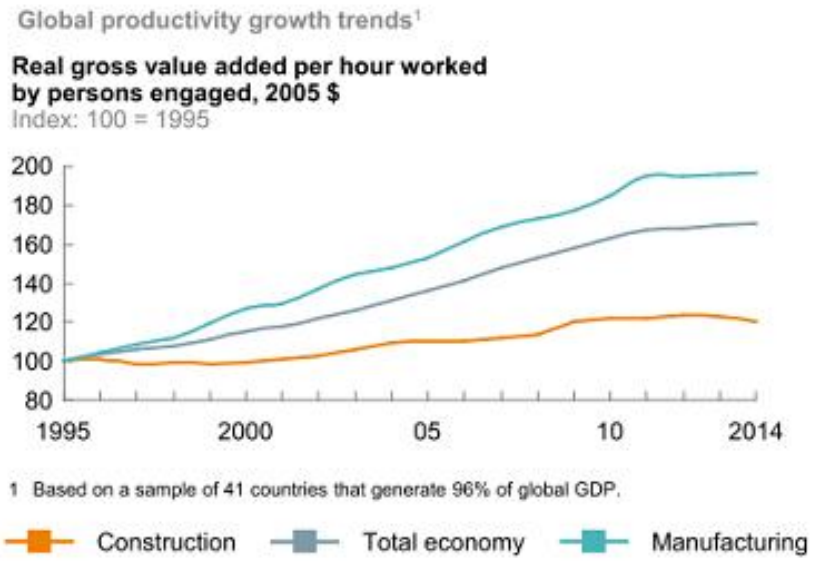


Figure 2.2. Real gross value added by persons engaged from 1995 to 2014. Image from Bughin et al. (2017).

In attempt to depict the development in Finland, a similar trend can be identified when comparing construction and manufacturing to the total value-added labor productivity in industries (see Figure 2.3).

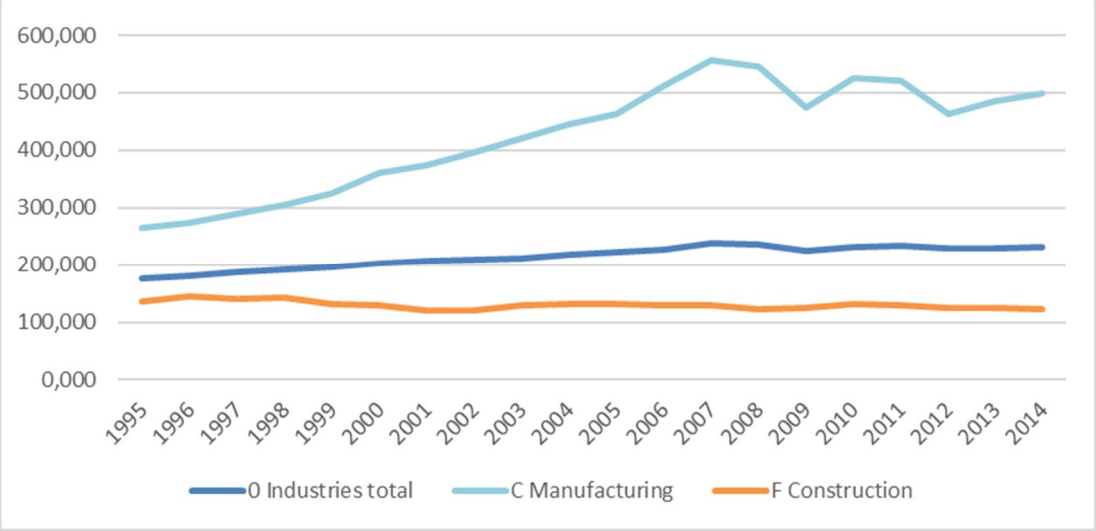


Figure 2.3. Value-added labor productivity by industry in Finland from 1995 to 2014, (1975 = 100). Data from OSF, Productivity surveys, (2018b).

When expanding the reference period from 1975 to 2016 (1975=100) and adding industries of agriculture, forestry and fishing (A) with mining and quarrying (B) for review, the differences become more illustrative (Figure 2.4). Koskenvesa et al. (2010) examined 12 construction tasks and their labor productivity from 1975–2008 in Finland and found that the progress has been in the range of 1% annually.

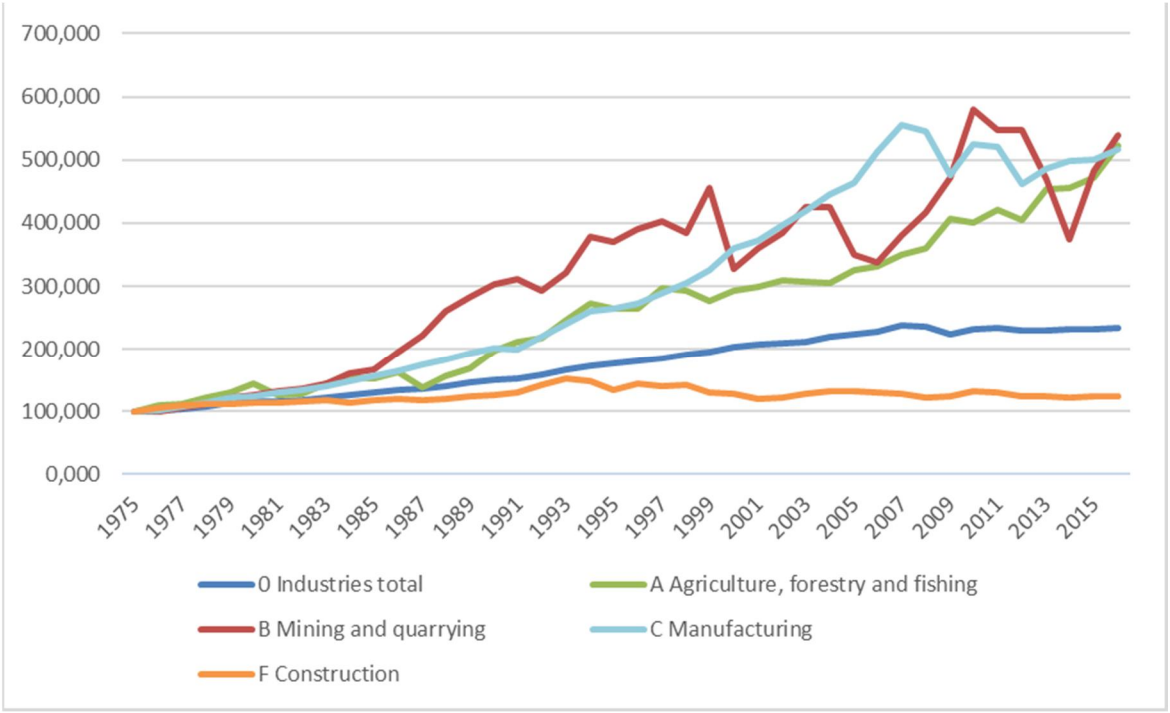


Figure 2.4. Labor productivity by industry in Finland 1975–2016, (1975 = 100). Data from OSF, Productivity surveys, (2018b).

Thus, it seems that little progress has been made, at least when comparing labor productivity with other industries. It is worth noting that the three figures above represent construction industry as a whole and are not directly representative of MC. Although not exhaustive, Bughin et al. (2017 p. 5) illustrate the differences in productivity between sectors in the U.S., indicating that specialty trades such as plumbing, roofing and framing lag compared to heavier construction sectors. Multifamily housing seems to be positioned slightly above the construction average in the U.S., however, the average compound annual growth rate of 2002–2012 seems to be negative.

According to the data presented by Bughin et al. (2017, p. 3), there are vast differences both in sub-sectors of construction and between regions. For example, in the U.S., heavy construction outperforms many smaller scale companies with higher fragmentation in the market such as flooring, roofing and framing in terms of compounded annual growth rate and productivity per person employed. However, it is debatable if comparing the construction industry with labor productivity metrics per se is reasonable. Sveikaukas et al. (2016) argue that the lack of quality output deflators for productivity growth in the construction sector possibly lead to inaccurate estimates. When addressing the perceived productivity hindrances in Finland, The Ministry of Finance (2018) in its working group on business cycles of construction industry referred to another study of Sveikauskas et al. (2018) where new productivity measures were introduced. The results showed that productivity growth has been positive and actually rather strong in three of four industries examined, which were single-family residential construction, multi-family residential construction and industrial construction. Only the construction of highways, roads and bridges did not show as positive results. Interestingly, when Bughin et al. (2017, p. 5) illustrated the labor productivity metrics in the U.S., this seemed to be the better performing area compared to the other three.

According to The Ministry of Finance (2018), the biggest difficulty in estimating productivity tends to be related to the vast differences in the properties of the built outputs and the difficulty of measuring quality as regulation has increased during the decades. Furthermore, differences in lots in construction projects adds another level of complexity to the estimates. Although measuring productivity may not be as straightforward as in other industries, it seems that the updated method presented by Sveikauskas et al. (2018)

seems to provide better output indices at least for the studied four sectors (Ministry of Finance, 2018). Therefore, it seems that the actual productivity may not be as poor as some statistics might point to. That said, the productivity of workers in some studies show that improvement could still be attained in construction sites. For instance, in Sweden, 30–35% of total production costs was a result of different kinds of 'waste' categorized in four main groups (Josephson & Saukkoriipi 2007). In the same report, construction workers' value-adding work time accounted for less than 17.5%, waiting time for approximately 23% and material handling took 14% of the work time. The researchers argue that the results indicate a low effectiveness. Naoum (2016) emphasized the importance of pre-construction activities when examining on-site labor productivity. Additionally, an extensive literature review highlighted the requirement for investing in technology and innovation for labor productivity enhancement (Naoum, 2016).

Off-site construction or prefabrication can be considered as one way of enhancing productivity. Off-site production can be seen to provide higher rates labor productivity compared to comparable on-site operations (Eastman & Sacks, 2008). Although adapting lean principles with off-site construction have been studied, the project-based nature in the industry coupled with cultural challenges were seen to hinder the progress (Höök & Stehn, 2008)

Public sectors can be seen to have an important role in pushing construction companies to adopting innovations. In some countries, it is mandatory for a company to provide plans designed using building information models (BIMs) to be even accepted to a bidding contract. (Bughin et al., 2017.)

2.2.2 The role of innovation

In economic theory, the role of innovation and advancements in technology are key factors affecting productivity. Innovation can be defined as *"the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method in business practices, workplace organization or external relations."* (OECD/Eurostat, 2005, p. 46). Moreover, viewpoints toward sustainability as a key driver in innovation has been discussed (see e.g., Nidumolu, Prahalad, & Rangaswami, 2009).

Conservative mind-set and lack of innovativeness are reoccurring critiques toward the construction industry (Bygballe & Ingemansson, 2014). The characteristics of the industry, such as complex, usually one-off projects, together with the varying degrees of regulation and successfully managing different stakeholder relationship are some explanations affecting the effectiveness (or ineffectiveness) for harnessing innovations. Emphasis on predictability and risk-aversion are generally seen desirable goals in the industry, as the end product itself is set to withstand decades of use and has to adhere to several requirements. Even though different types of innovation in external and internal network occur, conveying these innovations in every-day operation throughout the project-oriented line of business is a challenge. In order for achieving the benefits of innovations in both networks, development of inter-organizational communication, feedback processes and the active role of the management was seen important. It seems that the emphasis in companies tends to be focused on the internal network, however, a more harmonized level that includes activities of explorative and exploitative learning was suggested. (Bygballe & Ingemansson, 2014.)

In a case study of a Finnish construction firm, Matinaro and Liu (2015) found similar implications of low implementation of innovations partly due to the industry's cyclical characteristics and project-oriented working methods. The researchers emphasize that this is prevalent especially when higher rate of technology is involved. The underlying issue is not the lack of technological applications, but rather finding the most useful ones and overcoming more of the psychological attributes, such as attitudes, leadership skills, and organizational cultures. In addition to influencing attitudes, the results regarding to the case company showed that the controlling information related to BIMs and managing the BIM networks were relevant for better guaranteeing success. Furthermore, the results indicate that in order to increase the innovation adoption rate, cooperation and overall positivity toward e.g. BIMs and focusing on leadership skills rather than management skills should be advocated. (Matinaro & Liu, 2015.)

In another case study, Matinaro and Liu (2016) argue that innovativeness and sustainability in Finnish construction companies is closely bound in managerial talent and features of the existing organizational culture. Furthermore, similar educational backgrounds of employees can be seen to hinder innovativeness and recruiting employees from a more diverse background was seen advisable. Moreover, there seems to be a lack

of long-term innovation culture due to a more stringent focus on short-term cost and result-oriented actions.

Moreover, the researchers argue that the industry should accept the possible short-term costs for investments in innovation for potential gains in the longer term, even though changing the culture for enabling innovations was deemed difficult. They conclude that: *"It appears that organizational culture and diversity hold on the answers of the increasing innovativeness and sustainability including cleaner production in the Finnish construction industry and the case company."* (Matinaro & Liu, 2016, p. 14.)

Thus, the aforementioned studies suggest that at least partly, the lack innovativeness is due to the complex characteristics of the industry. However, influencing cooperation, learning, leadership skills, attitudes and other behavioral attributes would seem to affect more toward the critiques of conservativeness or lack of innovativeness than the supply of available technological applications per se.

2.3 Drivers and barriers of WMC

2.3.1 Overview

There has been previous studies toward current insights of experts in different parts of the value chain in the construction industry (see e.g., Hurmekoski, 2016; Laguarda Mallo & Espinoza, 2015) and future trends on wood construction (Haapio, 2013; Hurmekoski et al., 2015a; Hurmekoski, 2016; Toppinen et al., 2018b). Furthermore, studies concerning Swedish architects' influence (Roos, Woxblom, & McCluskey, 2010) perceptions, attitudes and interest toward the use of wood frames in WMC have been conducted (Hemström, Mahapatra, & Gustavsson, 2011). Additionally, perceptions from Finnish construction industry stakeholders toward barriers and opportunities in WMC have been presented (Ijäs, 2013; Riala & Ilola, 2014). A few of these studies and others will be examined in more detail in the following paragraphs among examining previous studies related to environmental, behavioral, cost and future aspects.

2.3.2 Environmental aspects

Many studies focusing on environmental aspects, such as the effects of wood product substitution in GHG balances have been conducted. For instance, Sathre and O'Connor

(2010) conducted a comparative analysis of 66 papers, which mostly relate to life cycle assessments (LCA) and substitution effects between wood and traditional construction materials. Subsequently, other studies relating to LCA, climate change mitigation in wood construction and substitution effects have been presented since 2010 (see e.g., Gustavsson & Sathre, 2011; Ritter, Skog, & Bergman, 2011; Skullestad, Bohne, & Lohne, 2016; Takano et al., 2015). A report conducted by Ruuska & Häkkinen (2012) assessed through a scenario analysis the GHG saving potential in Finland. The researchers compared the baseline scenario to alternative scenarios of the amount of wood used in new construction. The baseline scenario was created according to current relative share of concrete and wooden buildings with an assumption that between years 2010 and 2030 new construction production stays invariable. The alternative scenarios were calculated with different shares (22%, 55% or 82%) of wood construction. According to the assessments, the carbon intake grew approximately 10-fold, 25-fold and 40-fold respectively, when comparing to the baseline scenario. It is worth mentioning that there are differences in the wood-based comparison as well. Due to the different material mass in comparing CLT-structures and timber-framed structures, CLT-structures have an advantage in terms of carbon storing capacity, however, they do not perform as well when comparing annual GHG emissions. Nevertheless, all the scenarios compared to the baseline indicated that increased use of wood lowered annual GHG emissions.

Operational and embodied energy are commonly used terms in the context of LCA methods. Building-related use such as heating, cooling, lighting and other energy use with the inclusion of habitant consumption are considered to apply for the operational energy use phase (Ramesh, Prakash, & Shukla, 2010). Embodied energy accounts for the manufacturing phase, which includes raw material extraction, material production, transportation, construction and maintenance (Ramesh et al., 2010). However, as pointed out by Ibn-Mohammed, Greenough, Taylor, Ozawa-Meida and Acquaye (2013), the term of embodied energy may have various interpretations depending on the study. They continue to state that the usual interpretation of embodied energy is considered as 'Cradle-to Gate', which accounts all the primary energy consumed to the extent of completion before leaving the factory site. In contrast, 'Cradle-to-Grave' perspective takes into account the whole life cycle from manufacturing and use to the demolition phase (Ramesh et al., 2010), which would be the ideal option (Ibn-Mohammed et al., 2013). Figure 2.5 depicts these phases and modules in accordance with the European EN 15978 standard

(Hafner & Schäfer, 2017). According to a review of 73 cases across 13 countries, the life cycle emission analysis showed that embodied emissions accounted between 10–20% of office and residential buildings (Ramesh et al., 2010). When Ibn-Mohammed et al. (2013) summarized the most frequently cited researches on the relationship between operational and embodied emissions over the total life cycle of buildings, the 12 studies from six countries showed a variation of 2–80% with regards to the amount of embodied emissions. Thus, the difference is highly dependable of the materials used, structure types, location and estimated time periods. Furthermore, in colder climate areas where heating is used more, the ratio of embodied emission is lower compared to warmer regions (Ibn-Mohammed et al., 2013). With reference to other studies concerning LCA methods, Giesekam et al. (2014) point out that quite many studies do not take into account the technological development in more low-carbon energy supply, meaning that operational emissions may be over-emphasized more than reality would suggest.

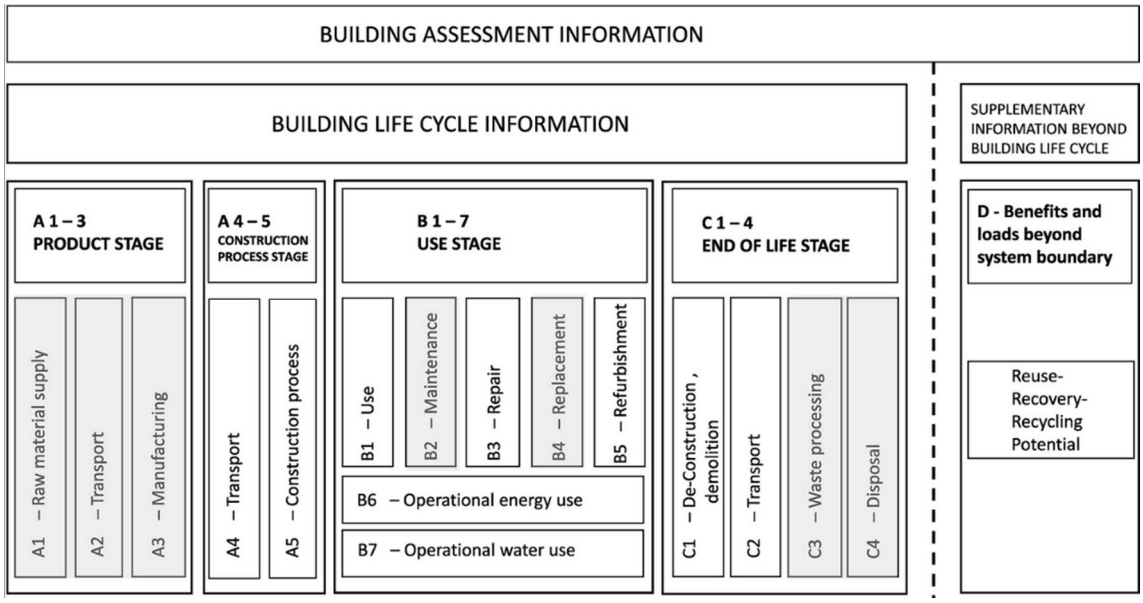


Figure 2.5. Building level framework for LCA. Image from Hafner and Schäfer (2017) based on the standard EN 15978:2012.

Comparative studies have shown that substituting wood in structural frames has provided benefits in providing lower levels of GHG emissions and environmental advantages (e.g., Hafner & Schäfer, 2017; Sathre & O'Connor, 2010; Skullestad et al., 2016).

Therefore, although the estimations vary depending on the estimated parameters and the selected range of modules (A–C) in each case, even from a conservative standpoint using wood products in construction can be seen affecting positively toward GHG reduction.

2.3.3 Power and attitude

Roos et al. (2010) applied Ajzen's (1991) theory of planned behavior as a conceptual framework in order to finding out how attitude, subjective norms and perceived behavioral control influence the intention of suggesting timber-frame concepts in building projects within Swedish architects and structural engineers. The results of each factors were further classified either as mainly negative, mainly positive or ambiguous. The similarities of barriers in the findings of Roos et al. (2010) and Riala and Ilola (2014) were related to sound performance properties favoring use of concrete and differences in the processes between the materials. Figure 2.6 depicts the power and attitude in terms of material selection between different stakeholders. According to the analysis of Roos et al. (2010), developers possess the highest influence over material selection followed by authorities and contractors, respectively. However, their attitude toward timber can be seen neutral or slightly negative.

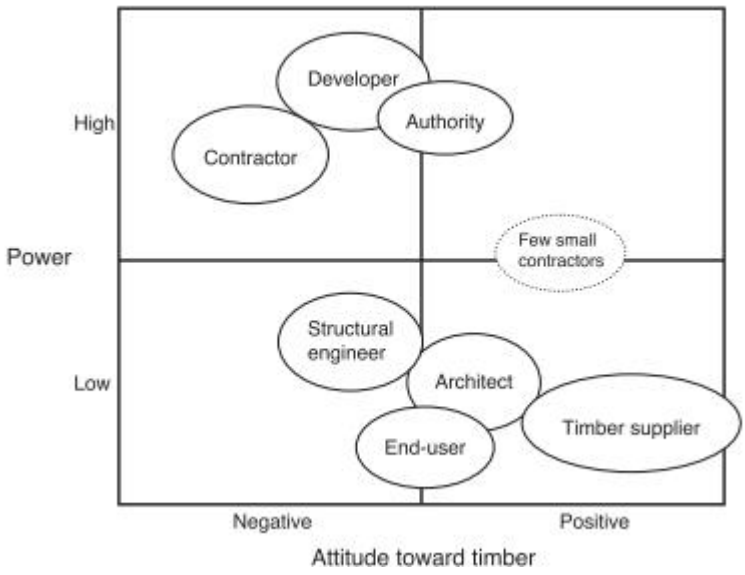


Figure 2.6. Power and attitude in the process of material selection. Image from Roos et al. (2010)

The developers are seen risk-averse and having a focus on costs whereas contractors' negative attitudes seem to stem from strong and long practices working with concrete (Roos et al., 2010).

Hemström et al. (2017a) adhered to the findings of Roos et al. (2010) when studying the perceptions of Swedish contract managers and their role toward selecting the structural frame in multifamily buildings. Additionally, the authors point out that previous studies relating to structural material preferences have not explicitly discerned the views of contractors from other respondents or, in instances where studies focused on contractors, they already had experience with WMC. According to the responses, contract managers had a significant influence in the material selection and are influenced by cognitive rules, which are present in concrete path dependency. Regarding the perceived cost disadvantages of wood frames, nine different aspect were identified. For example, need for weather protection on-site, higher supplier prices, high maintenance cost (presumably if used in cladding) and inexperience of construction workers were listed. Although environmental benefits for wood were seen among the majority of respondents, it did not affect the selection of the frame material in these buildings. However, if further impetus is placed on environmental aspects in buildings and wooden-framed solutions become more competitively priced, most of the respondents saw that the use wooden frames will increase in the future. (Hemström et al., 2017a.)

These attitudes are somewhat understandable as construction projects are usually expensive and differences in the calculations or realization of risks may affect the profitability of a project severely. Furthermore, for smaller contractors and developers, errors in either calculations or the construction phase itself can have relatively large and severe effects for the entire company. On the other hand, if the power in the material selection process is substantial and the overall attitude of toward timber is relatively negative particularly in the contractor's side, new or current players in the market could benefit from the situation by considering diversification strategies where the competition is not as severe as in the traditional line of building.

2.3.4 Barriers

Riala and Ilola (2014) examined the barriers and opportunities of WMC from 18 semi-structured interviews from stakeholders of three different positions in the building process value chain. The results showed that the main barriers were seen in the construction process, as concrete building is seen more advanced. Additionally, higher maintenance cost for WMC and concrete industry's robust stand were recognized as hindering aspects. The second research question regarded competitiveness against established solutions. Although newer solutions, such as CLT, were seen as improvements for the competitiveness for the use of wood, however, the lack of experience was widely acknowledged among the interviewees. It is worth noting that some respondents saw that the actions of public sector and promotional organizations have limited the competition against other materials when, for example, town plans favored wooden frames. Additionally, Riala and Ilola (2014) brought to attention that the more experienced professionals in WMC held a more critical the view toward the diffusion by great examples alone. Interestingly, this viewpoint cannot be seen as conclusive. For example, Hurmekoski (2016, p. 34) acknowledged this statement, but came to a rather opposite conclusion as successful reference projects were seen to have a potential in lowering the threshold for the actors in the construction industry value chain for advancing wood construction. Additionally, Haapio (2013, p. 26, 29) conducted a survey to different stakeholders and detected that good-quality reference projects play a key role in creating opportunities for WMCs current position. Toppinen et al. (2018a) also discussed the importance of continuous learning and reference projects. Riala and Ilola (2014) noticed a similarity in responses related to barriers of a study conducted by Roos et al. (2010), where the perceptions of Swedish architects and structural engineers were studied.

Gosselin et al. (2017) attempted to find barriers and motives from 53 published scientific articles. The researchers emphasized that the majority of the written literature sources researched encompassed the scenarios of WMC. Moreover, the perceptions found were mostly from architects and structural engineers. The researchers speculate that the reason for this is them having a more powerful role in the material selection. Interestingly, however, studies of Roos et al. (2010) and Hemström et al. (2017b) indicate that this perception cannot be seen as clear-cut, at least in the Swedish context, as highest power was accredited rather to other actors in the industry i.e. developers, authorities and

contractors. Nonetheless, the smaller amount of perceptions from other actors in the industry was acknowledged.

The main motive for using wood as a structural material by the frequency of citations with their respective relative weight was sustainability (31%) followed by technical aspects (22%), cost (20%), building erection speed (17%) and aesthetics (10%). Views concerning sustainability aspects showed the positive environmental capability of wood along with carbon sequestration properties. Conversely, the building codes were clearly identified as the main barrier for utilizing wood as a structural material with a frequency of 40%. The following barriers identified was the lack of expertise (18%), costs (16%), material durability (8%), technical aspects (8%), culture of the industry (6%) and material availability (4%). (Gosselin et al., 2017.) Although the study focused on barriers and motives for non-residential WMC, the scientific articles examined were subject to a broader view of WMC. The authors found the barriers consistent related to their study of non-residential WMC with the reviewed literature and cases studied. Interestingly, costs were both identified as a motivational and a hindering aspect.

Other ways of looking the possible barriers is through cultural, psychological or the levels of adopting innovations, which can potentially explain the current operating methods. For instance, Hurmekoski et al. (2015b) applied Rogers' (2003) diffusion of innovation-framework combined with a scenario analysis to identify key factors of WMC's market potential toward 2030. The combination of traditions in conventional buildings methods coupled with seeming path dependency of the industry are some barriers for adopting new innovations. In other words, path dependency in the construction industry can be seen as a hindrance to a larger adoption rate of wooden frames.

2.3.5 Estimates of costs

There has been different views toward the cost of WMC when compared to a concrete building. The range varies from being more expensive, relatively similar or even more cost efficient. For example, a wood construction project in Sweden showed that the costs were similar or less with wood than in concrete (Boverket, 2006 as cited in Mahapatra & Gustavsson, 2008). Through another review of existing studies, Mahapatra and Gustavsson (2009) could not conclude that compared to concrete-framed buildings,

wood-framed buildings would be more cost-efficient. As the share of material costs account for 25% for the total production cost in conventional multi-story buildings in Sweden, the authors emphasize that in the case of WMC, the focus in cost reduction should be rather in the building process and activities related to it rather than the frame material itself (Mahapatra & Gustavsson, 2009). Hence, moving up the learning curve through increased production (Mahapatra & Gustavsson 2009) and standardization of technical solutions (Hurmekoski et al., 2018; Karjalainen, 2002; Toppinen et al., 2018a) are some of the ways for increasing the competitiveness and cost-efficiency. Usually, the advantages accredited to wooden prefabricated elements can reduce the building speed thus affecting the costs-efficiency positively (e.g., Jones et al., 2016; Laguarda Mallo & Espinoza, 2015). Even indirect effects, such as occupational health benefits of quieter and safer on-site construction was seen in WMC (Riala & Ilola, 2014), which can carry potentially cost-reducing and better social aspects in the long run. In a construction project in the U.K., an 8-story CLT building resulted as cost neutral when compared to a comparative concrete building (Yates, Linegar, & Dujic, 2008). Even though the CLT project was 30% more expensive on paper, the building speed was one factors that led to a cost neutral solution when compared to a reinforced concrete frame typically built in that particular site (Yates et al., 2008).

However, the true evidence of costs is limited as many calculations rely heavily on assumptions and theoretical analysis of costs as identical projects with different frame materials are rarely built. A multi-story building project consisting of two nearly identical wooden-framed and two concrete buildings in Kuninkaantammi, Finland, is possibly the closest project providing for tangible information to the cost differences of these materials. The project additionally enables examining the living comfort, as the residential environment is the same. Unfortunately, no public documents were found for examining the cost differences in more detail.

2.3.6 Future insights

One complementary way of conducting futures studies is using Delphi methodologies. Toppinen et al. (2018b) conducted a two-round Delphi study for forestry, wood industry and construction sector experts consisting of interviews in the first round and an online survey in the second for finding perspectives of sustainability related issues and

development of wood construction toward the year 2030. The average professional experience of the respondents was approximately 15 years from which approximately 80% had experience of ten years or above. From the total of 19 respondents, 9 represented views from wood industry, 6 from forestry organizations and 3 from building industry. One of the findings showed that the primary reason for the growing popularity of WMC was regulatory aspects and broader awareness related to climate change. Furthermore, all of the respondents were seen to have at least a growing concern of sustainability. However, the more doubtful viewpoints were seen from the building industry representatives' side toward sustainability as a driver whereas the quality, aesthetics and end users' willingness to pay was regarded more significant.

The same methodology was used by Toppinen et al. (2018a), when internal and external factors affecting the future of WMC were assessed by interviewing Finnish and Swedish experts from forestry and wood industries (15), building industries (4), public sector (2) and 2 academic building industry experts. The study suggests that hybrid solutions (i.e. combining wood with other materials) could be one potential way of increasing wood utilization in buildings. Interestingly, it seemed that building contractors were not opposed of WMC per se, however, the role of e.g. wood industry companies in developing solutions was emphasized. Furthermore, focusing on external factors in areas of standardization of processes and internal factors related to standardization of knowledge and skills were seen as key aspects in growing the share of WMC. Additionally, addressing these aspects possibly result in cost-advantages as benefits in moving up the learning curve are enhanced. The researchers found that their findings are in line with Hemström et al. (2017a) in relation to cognitive pathways and with Hurmekoski et al. (2018) where the most promising avenue for WMC lies in industrial prefabrication.

Hurmekoski et al. (2018) the explored targets set by 2030 in Finnish WMC market through an explorative Delphi backcasting study. The data was gathered from experts in various sectors ranging from actors in wood construction value chain, governmental, non-governmental and construction industry stakeholders. Additionally, the analysis was conducted from dissensus and consensus viewpoints, which provided two ways of examining targets derived from the European Forest-based Sector Technology Platform and the European Construction Sector Technology Platform toward 2030. The results indicate that e.g. a vision for tripling the market share of WMC by 2030 in Finland was

reckoned improbable. Consensus was established in questions related to e.g. areas of improving education, adhering to regulatory obstacles e.g. in areas of fire regulation and standardizing the dimensions of the elements. Differences in opinion were particularly found regarding the measures of the public sector, however, adopting measures for pricing environmental externalities was supported among the majority (60% at minimum) of respondents. Although the targets visioned by 2030 were deemed improbable, the results indicate that developing industrial prefabrication methods and further harmonizing building codes were ways for promoting wood construction. (Hurmekoski et al., 2018.)

To conclude, there has been quantitative studies on different stakeholder group attitudes, qualitative studies for certain groups such as architects, wood product industry representatives and residents. However, based on reviewing previous studies, there has not been a qualitative study solely for Finnish construction firms that have no involvement in WMC. More specifically, there appear to be no studies in Finland with a focus on conventional building company's perceptions toward the current productivity of multi-story construction, insights for the effects of planned future environmental regulations and impressions of the future position of WMC in the Finnish context.

3 Theoretical Framework

As one of the goals of this study is finding future business environment possibilities through expert views and previous literature in WMC, the relatively well-known Five Forces framework introduced in 1979 by Michael E. Porter, was seen appropriate for the analysis. The Five Forces framework can be used as model in highlighting forces affecting a particular industry's competitiveness and furthermore implementing it in an individual company's strategy. Determining and analyzing the origins and possible causes, either as opportunities or threats, can enable finding strategies with an improved reward or even providing insights for implementing diversification strategies (Porter, 1979). The determining elements influencing competition in an industry are the bargaining power of suppliers, bargaining power of customers, threat of substitute products or services, threat of new entrants and rivalry within the industry (see Figure 3.1).

Reviewing the construction industry through this framework can aid identifying the current competitive environment and analyzing possible trends as either opportunities or threats in strategy formulation in a micro-level as well. According to Porter (1979) the best profit potential in an industry occurs when the combined strength of these forces are high and when reversed the chances for superior performance emerge**.**

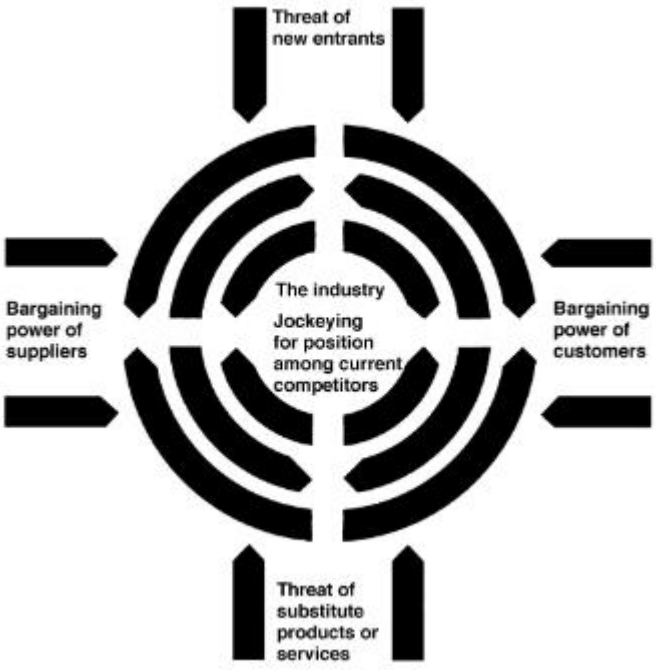


Figure 3.1. The Five Forces model. Image from Porter (1979).

The bargaining power of suppliers refers to the extent a supplier has the power of affecting the industry. According to Porter (1979) a supplier group is powerful if their industry has a high concentration level accompanied by a structure of few big players the industry it sells products or services. Furthermore, more power from the supplier side is gained if the product is unique or switching costs for the buyer are high. Additionally, the competition level of other substitute products play a role and if the supplier side has the resources and realistic possibilities for entering the industry it supplies. In some cases the supplier side may even possess a threat to the industry it supplies to when implementing viable e.g. vertical integration strategies. (Porter, 1979.)

At the other end of the spectrum, the bargaining power of customers can be inspected by purchase quantities and whether the products they purchase from the industry are differentiated or not. In cases where the differentiation level is low, the customers have a greater power of switching between companies thus increasing the competition and forcing incumbents to compete within the industry. In addition, some buyers can start producing their own products, which were previously bought from the industry. This threat of backward integration can be perceived as threat to the industry assuming that it is truly a viable option for the buyer. (Porter, 1979.)

Porter (1979) identifies economies of scale, product differentiation, capital requirements, cost disadvantages independent of size, access to distribution channels and government policy as six major barriers for entry. In other words, the stronger these barriers are, the less threat of new entrants is expected. Furthermore, if the current competitors take strong actions against the newcomer, the competitive threat obviously diminishes.

When it comes to the threat of substitute products or services it is rather clear that if the substitute product offers better technical advantages and value proposition compared to the industry's product, they usually come into use over time. Substitutes can become popular by an increasing rate if they are seen to produce the aforementioned benefits driving competition affecting in price reductions or improvements in performance within the industry. (Porter, 1979.)

The final force affecting an industry's competition is the internal competition within the industry where different tactics, such as pricing and marketing efforts, are applied. However, intense rivalry tends to be present when different factors are in play. These occur when the product or service has many competitors within a similar size range additionally not forgetting foreign competitors. Furthermore, slow industry growth, lack of differentiation and presence of multiple strategies are some of the other factors affecting the level of rivalry. (Porter, 1979.)

As of summer 2018, Porter's publication has been cited 54,288 times when searched in Google Scholar. Although the citation count is high, Grundy (2006) estimates that only 5% of management school graduates had used this framework in practice and between 15%–20% were familiar with it. Compared to the usage and awareness levels of SWOT-analysis the figures are approximately 50% and 95%, respectively. Grundy (2006) acknowledges that these are rough estimations, but there are also limitations for using this framework. For example, being too abstract for practical use, constraining in the sense of not taking account for other factors such as PEST-factors and current and the more flexible market situation since its creation. A refined version of the Porter's framework was thus created adding the elements of the original five forces with PEST factors, growth drivers and competitive position for a more thorough analysis of the overall competitive climate. (Grundy, 2006.)

For this study however, the classic Porter's framework was seen adequate due to the nature and the goals of this study as it enables observing a broader view of the industry rather than the competitive climate of an individual company. Further relevance and of these forces to the conventional Finnish multi-story construction industry and WMC will be assessed in Chapter 6 based on literature and expert interviews.

4 Methods and Data

4.1 Methods

The purpose of this thesis is to investigate specific stakeholder representatives' views within the construction industry and detect possible similarities or contradicting perspectives of other stakeholders in this industry. For getting in-depth views, semi-structured interviews were conducted. According to Bernard (2006, p. 212) semi-structured interviews are best in situations where the interviewer has only one chance of conducting the interview. Furthermore, semi-structured interviewing has its strengths when interviewing people of high professional status as they tend to appreciate the efficient use of time and the interview method demonstrates to the interviewee that there are well-considered questions within a scheduled time frame. Additionally, this format gives a freedom for stimulating conversation and for using different probing techniques, which can enable new insights. (Bernard, 2006, p. 212, 217.)

The issues of validity can be thought through errors and biases (Norris, 1997). Both in qualitative and quantitative studies, researchers are capable of mistakes. Furthermore, no form of research is immune to errors albeit the source of errors may vary. (Norris, 1997.) The term "reliability" in qualitative studies relates more in the quality of the gathered data and the activities done by the researcher rather than the traditional interpretation used in quantitative studies (Hirsjärvi & Hurme, 2001, p. 189). Lastly, it is important that ethical issues are addressed. Kvale (2007, p. 24) underlines that ethical issues should be adhered in every stage of the investigation. For example, ethical aspects include issues of consent, confidentiality, consequences and the integrity of the researcher (Kvale, 2007, pp. 24-30).

Although there is not any single correct way of conducting a qualitative research, it is possible to identify key components of qualitative methods, which adhere the design decisions. These key components can be distinguished as the relationship with interviewees, the sampling process, how the data is collected and data analysis. (Maxwell, 2009, pp. 233–234.)

As in any method, qualitative research has its limitations. Anderson (2010) highlights the aspects of personal biases and skills of a researcher that affect in the research quality.

Moreover, difficulties concerning rigor and processing large amounts of data can be seen as other limitations (Anderson, 2010). Analyzing and reporting the results can additionally be problematic, as there are no predefined models that the researcher can resort to (Hirsjärvi & Hurme, 2001, p. 35). It is also noteworthy that translating the results and quotes to English or vice versa can affect in interpreting or transferring subtle cues from respondents. According to Poland (2003), transcription quality is a topic rather typically neglected among qualitative researchers. In situations where transcription quality is adhered, the focus is usually on ensuring word-to-word accuracy. However, many of the nonverbal aspects cannot be fully incorporated to the transcribed text thus signifying that some incompleteness will exist even if the transcription is written verbatim. (Poland, 2003.)

Therefore, it is important to acknowledge these limitations and prevent the individual influences as much as possible for conducting a reliable and valid study.

4.2 Data

The data comprises of literature reviews and semi-structured interviews. Selecting the appropriate participants was done by purposeful sampling.

The interviews were conducted between May and September in 2018 to 10 construction industry executives, managers or people with an equivalent status mainly in areas related to procurement and production. The allotted time for the interview was 60 minutes. Before conducting the actual interviews, a pilot test interview was performed with a manager working in a construction industry organization. The purpose of this pilot interview was to experiment that the length of the interview was in line with the questions asked, get acquainted with the interviewing process as a whole and most importantly to get feedback about the questions. By doing so, the following interviews could be then conducted with more discipline and confidence. According to Kvale (2007, p. 46) pilot interviews are commonly used to test the level of understanding for the questions. The received feedback was positive in terms of the overall subject and questions. The only changes that were made after the test interview was adding two additional statements to the questionnaire.

The respondents were asked to rate the probability of seven (7) statements in a 5-point Likert-type scale in the latter part of the interview. The selected statements were translated from English into Finnish from previous studies conducted by Röhr (2016) and Toppinen et al. (2018b), where the future of multistory construction was studied amongst Finnish and Swedish experts mainly from the fields of wood industry or forestry. The statements selected for this study had either a high likelihood of occurrence toward 2030 among the interviewees in the previous studies or were seen more suitable for this particular context. Thus, it may point out similarities and discrepancies between different actors in the construction industry value chain. Although the results are not entirely comparable due to a different process, sample size and demographic factors, the possibility to see differences and similarities in perceptions on broader future trends are still possible. Moreover, if different perceptions occur, the possibilities for interesting insights may arise.

The selection process started out by searching companies mainly from the Confederation of Finnish Construction Industries RT (CFCI) between late 2017 and early 2018. According to their website (rakennusteollisuus.fi), CFCI is a joint interest organization representing member companies from building construction, construction product industry, infrastructure, HPAC contractor and surface contractor sectors. The relevant sector for this study is the sub-category of building construction sector companies. The search tool in CFCI's website enabled defining companies in more detail[1]. In this instance, the selected parameter was housing construction. From this, 54 companies were selected for further investigation. The first step was to examine the existing WMC housing stock and exclude those companies, which had experiences in building WMCs, because the aim was to get views from companies outside the realm of WMC. Next, the search focused on companies, which had built a multi-story residential building and excluding those, which had not. This was done by examining the companies' web pages "references"-sections or equivalent sections where completed projects were possible to inspect.

[1] The search tool has been modified since the selection process and is not identical with the previous form.

In order to further reducing the list of companies, the final selection was done more subjectively for defining the most suitable candidates. The selected companies had to fulfill at least one of the following criteria: (1) environmental values or sustainable development must be referred to in the company's mission, vision, values or strategy, (2) the completion of a BREEAM, LEED or other comparable sustainability certified project, or (3) implementations of innovative processes or products in the area of the construction industry.

After the selection process was completed, the contacting phase could be commenced. The objective was to call the selected companies' representatives starting with a formal introduction and presenting the purpose of the call. Moreover, anonymity of the interview was emphasized following with questions concerning the possibility for participation.

To touch upon the subject of ethicality discussed in Section 4.1, the amount of accepted degree of persuasion presented itself as a topical issue in preparing and conducting the telephone calls. According to Hirsjärvi and Hurme (2001), the amount of persuasion used and the ethical implications surrounding it, has been debated. As there is no intent to harm the interviewee in any way and no underlying financial gains regarding the interviewer, moderate and amicable amounts of persuasion can be applied (Hirsjärvi & Hurme, 2001, p. 85).

Studying and interviewing so-called "elites" usually have its own intricacies when compared to other groups (see e.g., Hertz & Imber, 1995). Although it is also debatable who accounts as a member of the "elite" – is it only board members of a company, a high ranking official in governments, or can a member of a company's management group be qualified as such? Harvey (2010) discusses the problematics of defining elites along with regional differences and the changeable status of the term. In this study, a similar approach applied by Rice (2010) was used. That is, rather than finding the individuals with the highest status, purposefully selecting "elites" who presumably possess abilities and in-depth knowledge for obtaining the most information regarding the interview questions.

The contacting process was always initiated with a telephone call. If the person did not answer the telephone, an email was sent. The email contained a brief and a similar

introduction as mentioned above. The recipients were given approximately two (2) weeks to answer the email. It is worth mentioning that the timeline was not told to the recipient, but served rather as a guiding principle acknowledging the reality that people in managerial positions are typically busy. If no answer was gotten, the process would start again with attempting to reach by telephone and then via email. The second email was paraphrased with a more colloquial tone than previously and sent again, or as expressed by Harvey (2010, p. 198): *"Researchers should be well-prepared to summarize their research briefly in non-academic jargon to subjects and appointment secretaries."* Finally, if no response was gotten after the series of attempts, it was seen best to move on and continue to contact other companies that passed the aforementioned screening.

In practice, however, the contacting process was not as straightforward and simple as on paper. The major problem was to get a reach by phone. Although not surprising, it proved to be a bigger hurdle than expected. However, when a call was answered the vast majority of individuals were receptive, co-operational and an interviewing time was mostly set at once. A more perplexing issue concerned the very low response rate of e-mails. In some cases, even if a consent was given on the phone and a mutual agreement for details concerning appointment dates communicating via e-mail was agreed upon, the low response rate was still evident. Overall, the acceptance rate for participating in the interview was high on condition that the communication was established.

Due to a technological mishap, one recording did not succeed. In one interview, there were unexpectedly two persons present. In the unsuccessful interview, the answers written to a separate paper regarding the presented statements remained. Thus, there are 11 individual answers concerning the statements and 10 respondents' interviews, which were possible to transcribe and analyze. Table 4.1 shows the position and approximate years of experience of the experts in more detail.

Table 4.1. Respondent information. Respondents in brackets are from the same company.

ID Number	Current Position	Years of Experience (Approx.)
1	Head of Production	27
2	Production and Development Director	20
3	Area Manager	34
4	(Executive Vice President)	38
5	(Area Manager)	30
6	Member of the Board of Directors	>21
7	Environment and Energy Director	31
8	Technical Director	25
9	Land Acquisition Director	32
10	Production Manager	19

4.2.1 Validity and reliability

The applied methods for this study proved to be suitable for answering the research questions, because the interviews gave an opportunity for discussion and various insights compared to a more structured survey.

The selection and contacting process was done without the assistance of any previous connections within the industry. In some instances when contacting possible interviewees, the contacted person suggested their colleague at the company, as they saw that they could provide more expertise for the research. The interviews were conducted in a similar setting (i.e. at the interviewees' office premises). Apart for one unforeseen instance, where there were two people present instead of one, the circumstances were in each case similar. The recordings were in the range of approx. 35 minutes to 60 minutes. In some instances, the interview exceeded the scheduled time of 60 minutes, but always on the experts' own initiative and agreement. In general, the allotted time for the majority of interviews was mostly fitting. Additional time would always be beneficial, however, respecting the experts' schedule was a priority. In retrospect, the most optimal time for some interviews would have been 75 minutes. Even though time use was supervised and

communicated during the interviews, some of the latter questions had to be gone through in a faster pace. This is probably due to the lack of experience of the interviewer or suboptimal amount of questions for the allotted time frame for some experts.

Reflecting on Poland's (2003) notion that transcription quality is often neglected, it could be said that in this thesis the focus was to provide the most accurate transcriptions as possible. To add, the problematics of analyzing mainly the content and not humor or gestures, the full nature of the interview is impossible to transcribe. Furthermore, translating the subtle nuances from colloquial Finnish into English proved to be challenging if not impossible in some parts and it may present e.g. some quotations rather bluntly. Therefore, the inherent problems of presenting transcribed results are present in this study as well. Despite these challenges, the most accurate depiction was strived for, as it can be considered as an influential aspect affecting validity (Anderson, 2010).

In the contacting phase and in each interview, the researcher introduced himself as a student of forest economics and marketing at the University of Helsinki. The "echo" of the word forest or forestry, especially in questions related to WMC, could have resulted in different answers if there would have been a student with a different major at a different university. However, the researcher does not consider that the experts would not have given their honest and professional opinion. In the actual interviews, the aim of the interviewer was to ask questions in a neutral tone and avoid making leading questions. When attempting to probe further insights, the strategy was to repeat the answer aloud for gaining certainty of the answer and then ask further questions based on the answer. Additionally, ethical issues such as confidentiality was stressed before each interview for inducing as genuine views as possible.

Reliability in qualitative research is linked with the accuracy of data representation and methods (Mason, 2002) along with replicability (Anderson, 2010). The semi-structured form enabled grouping and analyzing answers under a specific question, followed by representations and comparisons between them. Attention to representing the quotes from each respondent was given, however, absolute balance was not entirely achieved. Replicability could be attempted to some extent, however, the data representation would vary and conducting interviews would depend e.g. on personal abilities and interpersonal

skills of the researcher. Even if this study was conducted again with the same interviewees, the result would not be identical.

5 Results

5.1. Thematic sections

The interview design followed a set of questions revolving around three main themes of current residential constructions productivity, environmental aspects and viewpoints of future trends in residential multi-story construction in general, and the perceived role of WMC toward 2030 (see Annex 2). The results are presented in this chapter with these themes in mind. Furthermore, the viewpoints aim to answer the four research questions presented in paragraph 1.2, which will be addressed in the conclusions (Chapter 7).

5.2 Viewpoints on productivity

The first two interview questions addressed the respondents' perception how productivity has developed in residential multi-story construction during the past few decades, how should productivity be measured and was there any development needs for increasing productivity even further. Almost all respondents mentioned that productivity development has lagged from other industries or that it has been either low, non-existent or even declined from the past decades as follows:

> *"That's an interesting question. It has not been a "glory story", but we have very much transitioned into industrial prefabrication nowadays, however, there is still much handwork involved in different techniques as well."* [ID 7]

> *"The construction industry dozes in a way still. Even though the levels of industrial prefabrication, modular buildings and using large elements have increased, I just read from one study that just 30% of working time was used efficiently on-site. Sad but true. There's a lot of work in productivity still."* [ID 4]

> *"I would say that productivity has not risen at all, more like it has decreased. The reason being that bureaucracy, documentation and all this type of red tape eats up a lot more resources than before. The administrative side in construction is being over-emphasized nowadays […] moreover, building techniques have not significantly changed from the '70s. Masonry is identical and concrete elements are practically the same as they were in the '70s.* [ID 8]

However, one respondent did not agree with the apparently familiar implication of low productivity in the industry due to increased regulatory requirements over the past decades:

> *"Productivity has surely increased despite the news say that after the '70s no development [in productivity] has happened. I disagree, because in the '70s, you had the possibility of focusing solely in building and one superintendent could oversee the multi-story construction project whereas now you need three or four. Nowadays the regulations are considerately more stringent." [ID 3]*

Some of the mentioned reasons for this was the constantly increasing requirements and issues regarding zoning. One mentioned fragmentation within the industry and another noted that this is a global matter as well, as different countries or even cities in a country have different regulations, which partly explains the lack of global competition. For instance, the zoning processes and the need for unique solutions from municipalities was seen to inhibit the adoption for a more streamlined and efficient production:

> *"I have a feeling that urbanization and emergence of prefabricated concrete elements gave a productivity-leap in multi-story construction in the '70s, which enabled building similar buildings with similar structural designs through repetition…The philosophy since those days, how should I put it, has become more focused creating a more high-class cityscape. This has drifted toward creating unique town plans. Every project has to be created in a sense as a unique project i.e. you cannot do anything based on a sensible concept, but instead design always individually."* [ID 2]

Interestingly, three respondents draw examples from the automobile manufacturing industry when discussing the theme of productivity. It has to be left for speculation where that stems from, however, they are examples where a company can increase productivity by utilizing the effects of serial production and standardization.

> *"The largest problem in productivity development is this current zoning. Land-use begins from that each building has to be tailor-made. If you think that some development could even occur, it would mean that it is necessary to have some sort of series production as they do in the automobile industry. Not every Mercedes-Benz is different. In practice, it is always the same car, so I do not understand why it is thought that the building must be always different. This is the largest obstacle that you cannot have two identical buildings where learning, manufacturing methods or other would develop. The unit is always one. [ID 8]*

> *"It is always discussed why automobile industry is so seamless etc., but if you think that we have different locations, designs, 'planning orchestras' and employees then the construction company leading the project has nothing to do with the automobile industry, but are always in need of new solutions when a project is meant to be begun. You really cannot standardize it." [ID 5]*

One respondent discussed the problematics of zoning in similar fashion as above and gave an example of a German company where the concept of allowing the use construction

system where they could clone the building method i.e. the frame design and building services engineering was the same, resulting in substantial decreases in production costs in the past 15 years. He argued that they looked quite similar, but in no way bad or boring. In essence, issues related to zoning was seen to restrict the development of company-wide standardization processes and thus hindering productivity efficiency.

Although not directly part in the series of questions, opinions on project models, such as alliance model, was asked from a few respondents as this model has gained some positive attention e.g. in media in the past few years in infrastructure projects where some projects ran under schedule and budget. However, it was not generally seen as a miracle cure for residential multi-story construction.

> *"Not really. If you think about property development, where a construction company builds for itself, then they already have it under control and it would not really change dramatically it. The problem is rather in, if you view the big picture, how decisions are made and the effects of zoning and complaints which arise when decisions to build are made." [ID 7]*

> *"When talking with some people [who participated] of the few alliances that have been complimented in Finland…if you set budgets so high that certainly everyone gets a bonus then everyone says that it solves all things. But in my opinion e.g. in MC it is not really alliance that would…good cooperation, experienced and good contractors with whom doing frequent work in different projects – that helps." [ID 4]*

When asked about the measurements of productivity, the majority of answers mentioned the use of financial or accounting metrics such as cost-efficiency, profitability and different ratios of a project rather than the use of labor productivity metrics per se. One respondent elaborated ratios used at their company for comparing productivity and profitability between projects, which included financial ratios of return on capital employed (ROCE), margin and earnings before interest and taxes (EBIT). However, labor productivity was not seen unimportant as these quotes show:

> *"I think that we ought to somehow to able to measure and analyze working hours per cubic meter built and differentiate the building classes as they vary by technical standards and details." [ID 5]*

> *"Ultimately, the simplest way of measuring productivity is with euros. Production costs comprise of many components, which are dependent from the business model, but similarly from how much of waste and disturbances*

> *occur in the process itself, which need to be fixed afterwards. In that regard there is room for improvement. If I would have to appraise some amounts, we could enhance profitability and productivity by 10–15% just by eradicating various hassle." [ID 1]*

The question regarding development needs toward increasing productivity gave various answers. Developing processes, refining details and better synchronization of the various parts of the whole project was seen as an area of further improvement. One respondent emphasized the need for skilled employees. In addition, allowing building more stories in MC, lessening bureaucracy and allowing more freedom for standardization were mentioned. One respondent approached the theme of productivity coupled with sustainable development as minimizing waste and resources used in simplifying designs in the following way:

> *"I think we should understand in our society that sustainable development drives as toward minimizing waste and resources. E.g. building too special buildings is against sustainable development, because if we pay 30 % more for a building just for an intricate façade when we could, think e.g. from a societal perspective, build three of these 'gizmo-buildings' instead of building four pretty good quality buildings." [ID 2]*

The respondent continues to argue that people could live in newer, less consuming and overall sensible buildings. However, it would need concessions from authorities:

> *"It could work as a driver that authorities would bit by bit give opportunities for some repetitive production […] taking it further, we could use component technology to build an apartment." [ID 2]*

Overall, it seems that productivity was measured on a project-based financial productivity point of view. This is not to say that labor productivity is not measured, but the emphasis in productivity seems to be on a different spectrum compared to the macro-level productivity measurements.

5.3 Viewpoints on environmental factors

The respondents were asked in what way environmental aspects are present in their business operations and whether they use some specific measurements or metrics regarding this theme. In general, environmental aspects were not overly emphasized in business operations outside the legislative or regulatory regime.

> *"The firm does not count on environmental matters as such yet. In commercial real estate business, however, investors give value for e.g. LEED certifications [...], but in residential side there practically is not a comparable concepts that could be used in a project-level though." [ID 2]*

Some other respondents also mentioned the role of investors driving the demand of LEED or BREEAM in real estate construction:

> *"In real estate projects eco-friendliness is possibly where international investors, if the properties are resold, hope or demand the existence of these types of certificates. It serves somewhat of a guarantee that the construction has been done in accordance with regulations, although Finnish regulations are in many cases stricter than in LEED or BREEAM." [ID 8]*

In terms of measuring, the following quote summarizes the general viewpoint of not having additional metrics, because of the existing documentation needed for a construction project. Additionally, standardization enables estimating the amount of waste more accurately:

> *"We do not have special metrics. We do very accurate energy calculations, which the authorities already mandate and drives us to do it […] then there is of course the building process itself, working on-site etc. When we standardize the plans by doing similar constructions, we learn to work with very little waste. And the waste that is left, we sort it very properly." [ID 6]*

This is not to say that environmental aspects are not thought or taken into account. On the contrary, many respondents approached the theme from efficient material use, recyclability and energy production. Although recycling is mandatory, efficient material use is a win-win situation for the companies as accurate calculations for purchasing materials minimizes purchasing costs and later recycling costs in tandem with minimizing waste. Thus, from a cost-perspective, it is also monetarily beneficial for the companies to adhere these perspectives.

> *"In issues related to circular economy all our sites waste management derives from recycling, which is also economically beneficial. You could probably say it is custom in the industry." [ID 1]*

The regulatory and legislative demands served expectedly as a minimum threshold. When the respondents were asked to give one or two examples how the company has reacted to environmental requirements, a few mentioned that they have at minimum investigated the possibilities building a Joutsenmerkki® (transl. Nordic Swan) Ecolabel certified building.

> *"The Nordic Swan ecolabel is pretty strongly on display that we have reviewed what its position is in the market and is it something that influences demand or has effects on purchasing preferences." [ID 1]*

> *"In terms of classifications the Nordic Swan label is a new one. It is coming pretty strongly. It is ought to remember that these are subject to a charge and their goodness or badness is yet to be evaluated and what their true additional value is compared to what we already do within the framework of regulations. Nevertheless, investors demand those i.e. they want LEED and BREEAM rated buildings. [ID 7]*

In contrast to the visible demand of the investor side, consumer demand for more environmentally friendly solutions was not as visible in general for the respondents.

> *"When we look at our consumers, very few are willing to pay anything for energy-efficiency. We see that it actually comes from the regulatory side. The regulations are so tight and strict and they have become stricter every year, which makes the buildings so good on their own" [ID 6]*

> *"Well it [consumer demand] at the moment does not stand out […] at least it does not pay to invest to energy-efficiency, because people are not willing to pay for it yet." [ID 8]*

However, there are some case-specific exceptions as expressed in one interview when asked about possible consumer demand in the market:

> *"When we do our own production then we think what is the current trend and how should we respond to it. Consumers these days ask environmentally related factors even more than before and ask e.g. what energy class is this building" [ID 4] – "Yes, and they are even willing to pay for it." [ID 5]*

In other responses, energy production related factors were discussed. Some mentioned the consumer interest in especially in single-family housing production toward geothermal heat. However, these questions related to energy production were seen

relevant in MC as well. One respondent elaborated their way of proactively seeking different ways of producing and using energy for MC projects:

> *"We analyze for each and every zoning plan whether we will we join to the district heating network or will we produce local energy ourselves. Now we got an advanced innovation where we 'boost' from the ground with solar energy with solar collectors […] i.e. we will accrue 80% of the annual monetary savings to the housing cooperation with this, and it is in my opinion from an environmental perspective a significant accomplishment. [ID 9]*

The interview continued with showing the roadmap (see Figure 2.1) to the respondents. After they had a chance to be acquainted with the figure, they were asked to appraise how the possible implementation of the roadmap would affect their business. A few respondents had seen the figure before with varying degrees of familiarity. The key issues that stood out when reviewing all the answers were related to the schedule, regulatory guidance and calculation methods. The respondents who had previously been acquainted with the report, figure or both especially mentioned the possible problematics regarding the calculation methods as follows:

> *"We see that [the right way] is specifically in information and the figure's statutory steering of norms does not work. Frankly, it can lead to a political govern, where free and fair competition is intentionally influenced, because life-cycle assessment is pretty much tinkering with parameters." [ID 7]*

> *"This is not a new thought and of course carbon footprint is possibly somewhat problematic as there should be pretty clear rules of how it is calculated." [ID 1]*

The figures norm steering was mentioned also in some other interviews when asked about the possible effects on business. One respondent expressed this view and additionally discussed the effects of lobbying as follows:

> *"The steering of norms is the thing that raises hackles […] we already see that these are lobbed. In many cases, these are lobbed and, in many cases, we go wrong with them, as we do not recognize different demanding solutions in building. Instead, we homogenize them with these regulations to a certain kind of form. […] I argue that this regulatory steering is the Achilles heel in Finland […] If you ask this from building professionals or the building materials industry you'll get various opinions of which is actually better. Is it concrete or is it wood and they [lobbyists] both have*

really good arguments […] the question is then that which one puts more money toward that they get more pleasant norms and that's why it is…I don't know…it is where lies the danger in this." [ID 9]

Another viewpoint discussed the need for minimizing statutory steering and saw that the resolution should come from markets as follows:

"Well I have feeling that I would preferably let the market steer this rather that begin forcibly do something on a regulatory level, which are not necessarily thought through […] We can get new problems, which we did not even know about. This is why I would be very careful about the authoritative steering in this." [ID 6]

In addition, some respondents mentioned that it would affect the construction prices increasingly:

"This will affect simply to the price of the product. Building costs will increase." [ID 10]

From a business perspective, it was also seen relevant to ask about the financial steering illustrated in the figure. More specifically, what the respondents saw as favorable incentives, which would lead to the best outcomes. Few mentioned that the end-user will eventually carry the costs and one mentioned that one solution could be that incentives should be directed at end-users rather than to the company:

"I do not really see much value with which incentives you would… I actually would leave that box unused. If the [financial] incentives would be directed to the end-user who wants for some reason more than the law requires, I think that it would be in a way the right place, because if she/he can afford paying more from the product and then it would become more easily applicable for the product. If it [incentive] would be directed here [to the company] then I do not think it is necessarily wise. It does not necessarily go to the right place." [ID 4]

Additionally, actions toward easing some regulatory demands and zoning requirements were seen to be even more preferred rather than direct financial incentives in some discussions.

"If you were told e.g. that you do not have to build a bomb shelter there given that you build this sort of a life-cycle then it could really have a

monetary advantage […] if there could be given in some statute that you would get easement by doing a lower emission building by its carbon footprint or life-cycle then it could help."[ID 4]

"In zoning we could achieve a lot. When city plans are made and zoned for buildings projects there is possible to gain much monetary benefits […] in many cases it steered so far e.g. what material needs to be used, the building's shape, plot ratios etc. That would probably be the best way allowing slight liberties." [ID 10]

Lastly, it could be said that the figure's financial incentives remained rather unclear among many respondents. That is, they pondered what would the actual incentives be and how they would be implemented.

5.4 Viewpoints on future trends toward 2030

Viewpoints related to future trends were asked with four questions in which one part included giving opinions to seven statements in a 5-point Likert scale. First, the respondents were asked to mention two or three trends in the residential MC industry toward 2030. Mostly, the viewpoints concentrated in the building process and improving efficiency although social and environmental aspects were discussed. The most frequently seen trend was prefabrication and various improvements toward it. Additionally, some mentioned specifically that the trend would be in modular building as this quote shows:

"I would assume that firstly, industrial prefabrication will increase substantially […] it would enable building modules in dry conditions, which would then be hauled sheltered on-site." [ID 3]

In relation to WMC, the same respondent saw that modularization would be especially a possibility for wood, as transporting and hoisting modules built with reinforced steel and concrete is more challenging due to weight differences. It is also worth pointing out that the respondent was one of two experts mentioning WMC as a trend toward 2030 under this particular question:

"Well wood construction is probably the other [trend], because it is possible to reach reasonably strong, durable and yet relatively lightweight structures […] modules will be of course large in size, but weight has to be of course be controlled that they could be transported and hoisted. It cannot be heavy concrete or steel stuff. And it is not necessarily a bad thing,

renewable wood could be then used and in Finland there is still enough forests." [ID 3]

A similar notion of combining modular building with the established building practice came from another respondent when asked about the possibilities of modular construction when the trend of using prefabricated elements was first discussed. It is worth specifying that the respondent was predicting the trend of replacing concrete elements from cast-in-place concrete more than before. Additionally, as mentioned by some other respondents as well, the respondent discussed that using modular elements in e.g. bathrooms is already a rather established practice and not a new phenomenon. However, the possibility of modular building was not seen as a valid solution for concrete in a larger scale as this quote shows:

"No. Problems will arise from them, especially when making from concrete, as they weigh like hell [sic] that you cannot transport them." [ID 10]

The only other respondent that mentioned WMC as a trend saw firstly that discharges from materials e.g. glue contents and levels of various chemicals would decrease and overall emphasis on indoor air quality would increase. The second trend was seen in structural solutions toward the use of wood, however, in design solutions it was not seen as contemporary as follows:

"I would believe that wood usage will definitely increase in multi-story construction. In design solutions I think it's kind of fake and it is many places an economically cheap solution." [ID 9]

Some other trends and words that the experts mentioned verbatim toward 2030 were digitalization, robotics, smart materials, further improvements to building information models (BIMs), focus on indoor air quality, urbanization, affordability and energy efficiency. For instance, these two examples below give some examples how the technology-related viewpoints were expressed:

"BIMs and its data content will be used and on the other hand, current mechanisms will be questioned. In the future, gathered information from

design modelling, new technology and in fact also from robotics. It will come to building as well…it is not that far off […] but this type of prefabrication procedure, maybe packaging things in a new way, which are design solutions, modular solutions and are based on BIMs and using that information in production, whether it being in the process-side in a factory or in on-site conditions." [ID 1]

"I think that one trend is that increasingly we will begin making components for different elements of construction. Whether it will come from one producer or from a consortium, but fitting them preferably in one place in a way that the component will be brought and assembled into the thing. That is probably one [thing] i.e. the product development, component development and concept development." [ID 2]

Some of the more troublesome trends included questioning the outcomes of consolidations to the market, which have been present in planning companies and to an extent in the construction companies, the effect on urbanization to the Finnish housing market and concerns on labor force. One example of labor shortage coupled with a future trend was expressed as follows:

"Another [trend] is of course that we have a massive labor shortage. We cannot do this kind of manual work because there is little sense in it. This cannot continue this way that we do manual work. We will use robots to produce components, which can be assembled in a simple way – that is the direction we will go [as an industry]." [ID 2]

The effects of urbanization and its relations to the purchasing power of consumers in the Greater Helsinki area and other larger cities was a subject of discussion amongst a few experts:

"You know that we are now in the trend that we are forced to do smaller apartments, because people do not have the money. I think about the migration to cities and what comes with it as people concentrate increasingly to university towns…when the lights shut off in other places and what it will bring forth." [ID 4]

"Well one troublesome trend is that apartment sizes have in past 10 years decreased significantly. Functionality remains the same that you have a bedroom and a kitchen, but all spaces are reduced. If this trend continues and we do not build anything else but studio apartments, then that is in a way a bad trend." [ID 8]

The latter quote led to probe a little further, because the general notion of sales prices per square meter in studios are higher than in larger apartments in the same building. Additionally, one might presume that the margins tend to be higher in small apartments thus favoring the construction of smaller apartments from the company's viewpoint. However, the respondent mentioned that by building only studios the profit margin would not be better than building larger apartments for families, because bathrooms and kitchens are the most expensive parts. That is, building a larger apartment compared to two smaller apartments with twice the amount of kitchens and bathrooms would be more inexpensive to build. A similar question was asked from another respondent, whether building more studios is a positive or negative trend as they discussed that they are forced to build small one or two-bedroom apartments:

> *"I think it is neither [good or bad], but inevitable as people cannot buy a 100 m^2 three-bedroom apartment. Instead, they can only buy a 70-m2 three-bedroom apartment, because they do not have the money. When the average person earns 2,500 euros then he/she cannot settle to the Greater Helsinki area […] When the person moves from elsewhere it can be that the apartment he/she owns in the countryside does not have any value, because there are not markets for selling it i.e. the person comes here empty-handed, so we must resolve this issue. Surely the trend that we build small and efficient apartments will not decrease even though cities try to force us that there should be a certain average m^2-area in the building." [ID 4]*

Although it was also mentioned that municipalities have lowered the restrictions for average square meter for buildings, but they are apparently discretionary decisions. The respondent mentioned that they have sites in the pipeline with a mandated square meter average of 70 m^2.

Next, the experts were asked to give numerical answers to seven statements, which were given in a separate sheet. To recapitulate, the statements were selected from the studies of Röhr (2016) and Toppinen et al. (2018b). Some of the respondents gave autonomously arguments for their viewpoints. In a few cases, the respondents were asked opinions if the interviewer noticed in-situ extreme values i.e. opinions numbered either 1 or 5. Due to time constraints, however, this was not possible in many of the cases. Answers to these statements are presented in Figure 5.1 and Table 5.1. It is worth noting that the answers from the test interview are included and the later added two statements thereafter. This explains the reason of the discrepancy of total answers in the last two statements (i.e. 10

responses instead of 11). Although the recordings from one interview did not remain, the answers were successfully included herein, because they were given in a physical form.

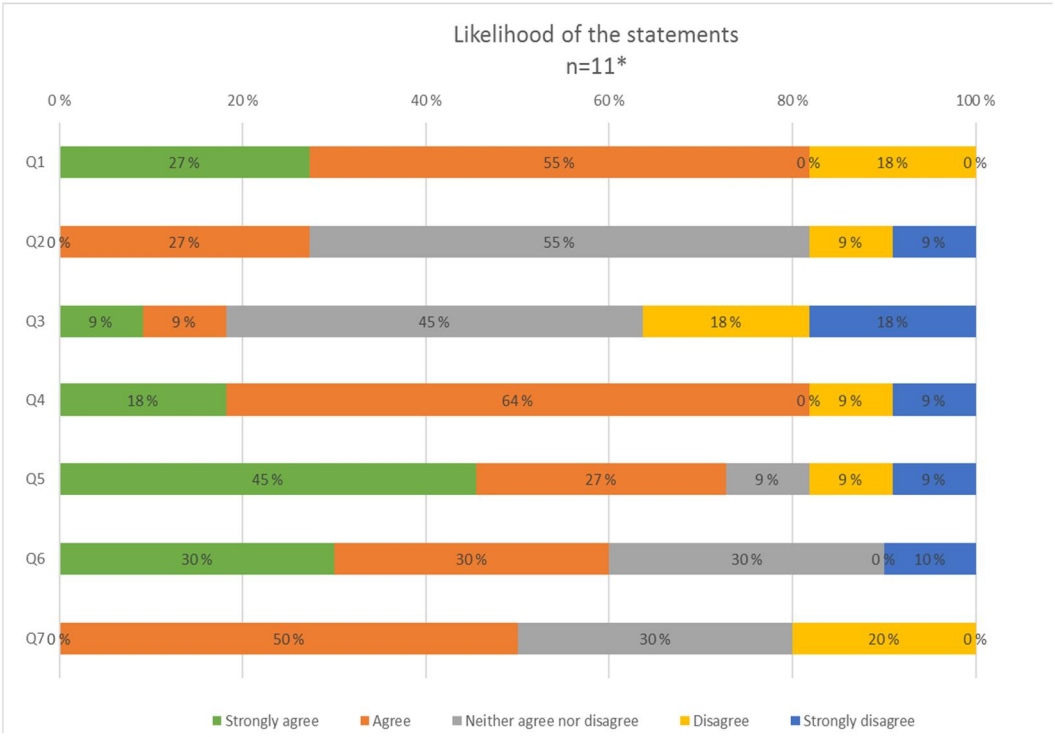


Figure 5.1. “Likelihood of …” statements among construction industry experts.

Table 5.1. “Likelihood of …” statements among construction industry experts.

Statements	Total	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree	TOTAL
Q1. By 2030, counting for life cycle costs of buildings and not just purchase prices will have significantly more effect on the decision making in large-scale building projects.	11	27 %	55 %	0 %	18 %	0 %	100 %
Q2. By 2030, the consumer demand for sustainable living is a significantly stronger driver for wood construction.	11	0 %	27 %	55 %	9 %	9 %	100 %
Q3. By 2030, consumers will see wood construction as a modern way of building.	11	9 %	9 %	45 %	18 %	18 %	100 %
Q4. Future certification schemes will be difficult to manage for smaller businesses, due to the bureaucracy involved.	11	18 %	64 %	0 %	9 %	9 %	100 %
Q5. The future of wood building is in hybrid buildings, using jointly other materials such as concrete and steel where it brings the most benefits.	11	45 %	27 %	9 %	9 %	9 %	100 %
Q6. By 2030, prefabrication will be the main operating logic, with less on site building.	10	30 %	30 %	30 %	0 %	10 %	100 %
Q7. By 2030, wooden interiors have become a trend preferred by consumers.	10	0 %	50 %	30 %	20 %	0 %	100 %

Overall, the likelihood of statements 1, 4 and 5 had the most answers for either "strongly agree" or "agree" with a combined total of 82%, 82% and 72%, respectively. However, statement number 5 *"The future of wood building is in hybrid buildings, using jointly other materials such as concrete and steel where it brings the most benefits*" had the most "strongly agree" answers with 45%. Conversely, least likelihood was seen concerning statement number 3 *"By 2030, consumers will see wood construction as a modern way of building"* with an 18% rate in both "disagree" and "strongly disagree" answers. Statement number 7 can be considered the most neutral due to the absence of answers "strongly agree" and "strongly disagree". However, the most neutral likelihood in absolute terms was statement number 2 with a 55% rate of choice "neither agree nor disagree". In order to delve deeper to the experts' viewpoints, some of the comments will be presented below.

Regarding the first statement *"By 2030, counting for life cycle costs of buildings and not just purchase prices will have significantly more effect on the decision making in large-scale building projects"* the likelihood was deemed high.

> *"Life-cycle costing is still relevant to this day, but there should definitely be included an aggregate economic/gross/total economic review as in public projects have been done and of course it will be a very likely option." [ID 1]*

> *"Yes. This first one clearly. It already shows." [ID 2]*

> *"Now here [in the first option] this is more related to public projects and not so much in private or investor-driven projects…well maybe there is [seen] in some ways." [ID 9]*

As mentioned above, the second statement *"By 2030, the consumer demand for sustainable living is a significantly stronger driver for wood construction*" had the most "neither agree nor disagree" selections. One respondent wrote to the paper "for concrete also" and discussed that it is a driver for all production. Other commenters held a similar view.

> *"Environmental consciousness will definitely affect consumer demand and will it be driver for WMC, it can be that maybe, but it depends also to what*

direction WMC will go and what other solutions we will have, because there are other good options which we are not necessarily aware of. Composite materials or steel sandwich structures or to other related solutions, which is then a question how we calculate different things. However, I would believe that there is more demand for that sort of thing [sustainable living]." [ID 1]

"This your second is in a sense a 'killer' that [continues to read the question aloud] this I do not believe at all. It may be a driver for product development, but will it drive specifically wood production, it will drive all production equally. So I don't really…surely for WMC as well, but I think consumer demand steers toward it that we develop this environmental-consciousness. It is obvious, but it concerns everything." [ID 2]

"I would rather consider for all building. I'll put only number 3, because I think it will affect, but it relates to it that wood has to answer all of these questions sooner or later more comprehensively. It is good to remember that as there are so few WMCs, we really do not have knowledge about it. We should analyze how those old buildings have been affected by time." [ID 7]

"[Reads the statement aloud] I do not really…I do not know is it environmental consciousness. I think WMC should be just one way of doing. It could be also done e.g. from blocks, steel or anything. It should be that it is technically sensible to build in a way that people get a slightly different building, but I do not know whether it is environmental…I don't consider environmental-consciousness as a basis for it. I would rather base it toward considering that a person can equally live in a concrete building or he/she can live in a wooden building." [ID 8]

Regarding the third statement "*By 2030, consumers will see wood construction as a modern way of building"*, which had the most answers not supporting the view with 36% (*n*=4). One mentioned that 2030 will be too soon for WMC to break through and become in that sense modern. Two respondents mentioned that WMC is not favorable when stories increase.

"I would say that not much, if especially stories will increase, then WMC does not support that stories increase a lot [...] well let's put it this way: it should not be mixed everywhere. There should be reserved own areas for it where they form an own ensemble, own neighborhood or something like that." [ID 8]

In one in-situ instance where it was noticeable that a response was marked as "strongly disagree" and asked for reasoning of this viewpoint the answer was the following:

> *"No. It is not going to be a significant thing. People will not view it as a modern way of build at that time. If that year were 2040, I would then choose option number 3. I don't think it will be a large driver in that sense." [ID 9]*

However, there were views on the other spectrum as follows although similarly building many stories from wood was not favored:

> *"I would keep it as a modern way of building already in MC. It is not sensible to build very high buildings from wood, concrete is superior in that and partly steel. What do I answer if it already is modern? [Laughs]. There's no oddness in it, but once again, markets will determine that." [ID 7]*

Considering the fourth statement, "*Future certification schemes will be difficult to manage for smaller businesses, due to the bureaucracy involved",* every respondent had a clear opinion in the sense that no one answered the option "neither agree nor disagree". On one side bureaucracy was seen a problem especially for smaller incumbents. On the other hand, bureaucracy was not as a problem per se, but rather the lack of knowledge.

> *"In general, certification schemes cause problems for smaller companies." [ID 1]*

> *"Yes. Unfortunately, yes. I fear this seriously. We are heading excessively toward that." [ID 7]*

> *"Not in my view. You cannot make it that difficult with legislation that it was not possible to build." [ID 8]*

> *"I would not say that bureaucracy is the problem, but smaller do not have the knowledge […] of course some sort of bureaucracy burdens, but they are not that heavy that I think it is more of a question of know-how." [ID 2]*

The most likely viewpoint was given to the statement *"The future of wood building is in hybrid buildings, using jointly other materials such as concrete and steel where it brings the most benefits*" amongst 45% (*n*=6) of the respondents. In retrospect, however, the answers inclined toward a viewpoint, where wood could be used e.g. in façades rather than as a structural material as these quotes show:

"I think that hybrid building is a likely scenario, because wood is not always the best material in all places, but combining different solutions and continuing toward that direction is probably appropriate. We [in the company] have similar thoughts." [ID 1]

"Hmm...Well one example of this could be a building, where the frame could be concrete and facades from wood. There could be a large likelihood for that sort of hybrid construction." [ID 8]

"Well this is a good question. I particularly believe that using steel frames could be the future trick, in which many things could be utilized […] I once investigated, whether it would be a technically expensive solution to manufacture a steel-frame, which would then be cladded with timber elements. It would be technically easy to do these days and in that case, the outer walls, because they should be able to breathe, could be done breathable. Then there could be a steel frame, which would be good for meeting fire regulations. But as you may know, steel building is considered as foolery [in Finland]. If you look at Central-Europe, they put instantly a steel frame whenever there is higher construction. In Finland not. In Finland, everything is made from concrete." [ID 9]

One respondent explicitly emphasized that it was better to stay in one selected material in a project as whenever many materials are combined more contractors are at play which may increase inefficiencies in production and different behavior of material can lead to structural and quality problems.

"Firstly, we should stay in one frame structure. The more we mix them the more problems will arise in structures and various difficulties in the lifetime toward durability and quality appear. Also it will bring inefficiency to the production […] That I understand when mostly concrete is used when coming to first floor that the foundation is in order and then going upwards with wood. But if you start combining them between floors, then it becomes a little worse." [ID 2]

The sixth statement *"By 2030, prefabrication will be the main operating logic, with less on site building"* gave an equal distribution in choices between 3–5. An answer with an estimated high likelihood can be summed as:

"It is likely that industrial prefabrication will clearly strengthen and reduce on-site working. It is maybe more assembly and installation there [on-site]." [ID 1]

The only opposing comment was more reflected by the view toward the vast adoption of modular building, because the respondent mentioned that in practice every building is nowadays based in the use of precast concrete as follows:

> *"Well this is a bit of a weird question [reads aloud]. I am not aware of any such buildings that are made cast-in-place nowadays in Finland. Basically all offices and apartments are based on the use of precast concrete, which are manufactured industrially somewhere […] if prefabrication means modular units, then this is not likely that it would be the predominant operating logic." [ID 8]*

The last statement raised the question among many of how it could be increased beyond current usage. Wood panels in interior design was seen as a possible solution as already wood is highly used in flooring and in other fixtures and fittings.

> *"[Reads aloud] well it could be. But, admittedly, there are just few of that kind of interior solutions." [ID 8]*

The interviews continued with two final questions after the experts estimated the statements. The other aimed to provide viewpoints to whether WMC was seen more as a competitor or did the experts see possibilities for more extensive cooperation. This question gave various opinions ranging from all ends of the spectrum. Some experts saw that WMC and cooperation was definitely a possibility and did not mention WMC a competitor. Some mentioned with a more cautious or neutral tone that cooperation is seen as a possibility and with varying degrees related to the question of seeing WMC as competitor. There was only one clearly stated response where a representative did not see WMC as a competitor and as a possibility for cooperation. Additionally, a viewpoint from a company that focused mainly on contracting did mention that for them material choice was insignificant. Overall, however, the range of answers can be seen inclined toward a mindset favoring cooperation with WMC rather than not. The following quotes demonstrate the different viewpoints in discussion:

> *"We see it [WMC] as cooperative possibility without question, we just do not have a lot of experience with it yet. There is now perhaps a situation that the eagerness from the wood products industry for creating solutions has somewhat run out [laughter]. This sort of trend has been visible that there has been an objective to build wood panel BES standard [RunkoPes] i.e. these types of BIMs which was completed to a certain degree, but now*

that they did not become commercially widespread, the zeal has pretty much ended." [ID 1]

"I see that part of our production could be wood construction i.e. it is possible. It is a possibility and it is nowadays occasional construction still. That, why it could not be permanent, a sort of established practice in business, I mainly see it that now should be involved in it to gaining experiences and assessing what to make of it." [ID 8]

"Definitely a possibility […] Where I see its utility is in sort of comprehensive production – the whole frame and all building. In an ideal situation there would be a factory that produces this [WMC] as in ready blocks and installed them in place where we point to on top of common areas made by us, which are all made from concrete: bomb shelters, common facilities etc. and on top of them would come the apartment blocks in wooden modules. And then the modular building should be adaptable from inside. As you know, all of these forest industry companies have their own desire for "we would do it this way" and then they sort of do it the hard way. There is no comprehensive standard – when that is achieved the factories could focus on not that how my way would be the right way, but instead they would do that block just like a sandwich element has certain dimensions, requirements etc." [ID 9]

According to one respondent representing a contractor's viewpoint, the material did not seem to matter:

"I think it is all the same, whether it being wood or concrete from our i.e. from contractor's view it does not matter." [ID 3]

An example for a more neutral, but rather contradictory statement in retrospect was stated as follows:

"We see it as a cooperation. We do not see it as a competitor. Wood can be used in specific parts of MC quite well. It is quite suitable there, but we would want to keep it out from the actual frame and facades, because… [inaudible]." [ID 6]

Regarding the most clearly stated comment of an opposing view for any foreseeable cooperative actions and not seeing WMC as a competitor were argued by reflecting the lack of experience and budgeting problems as part of inexperience and the need for more detailed design requirements.

"[I] do not see and it is not a competitor. That's just how it is. It won't come here." [ID 10]

When asked whether it is not a competitor because it is not a threat or for some other reason, the discussion continued as follows:

"It is not a threat nor a competitor. Every once in a while someone does a WMC and after that they leave it [at that]. There just is not…that is to say that because it [WMC] has not been done much, so people do not have a proper cost awareness to what it will cost all things considered." [ID 10]

In another discussion revolving around the same question and in connection to the quote above touching on the attitudes or culture of the industry where there is not apparently a developmental process as perhaps in many other industries as this quote shows:

"But then you stumble there, because there is not this type of developmental process in the construction industry. We have it like this: 'Oh ok, this went wrong, shit happens, let's try something else'. That is why I don't believe that even toward the year 2030 this WMC will substantially make progress…in Finland." [ID 2]

However, the aforementioned respondent did not clearly state an explicit answer, but gave his insights with relation to WMC as follows:

"Well the challenge in in WMC is that I do not believe that you will find easily a construction company, which would be prepared to build a WMC for private buyers, because our Housing Transactions Act sets many conditions on how the building performs […]. It can start to resolve in that way as it already has begun that some real-estate investors have agreed to do them, in which case we get experience from the construction and operating phase. Assuming that the solutions are good, assuming that there will come successes instead of failures let's say in the construction phase, because the feedback from construction companies is currently that budgets have not realized, the buildings have not become any cheaper than concrete buildings and that they have not been built any faster than concrete buildings." [ID 2]

To follow the notion that WMCs have not been built any faster, the arguments for construction speed in WMC were not seen convincing or meaningful enough among the

few respondents with whom this aspect was discussed. This argument was expressed by the interviewer e.g. in instances where higher costs of WMC was discussed.

> *"A basic MC will take 14–16 months to build meaning that the frame's share is approx. 2 weeks/floor. Therefore, if we have 8 floors, the concrete frame's share is 16 weeks. If you could e.g. half the time with wooden panels, it would be 2 months from the 14–16 months. We don't see that there is a huge relevance there. Moreover, the probability for errors increase fast if some factory faces problems in making modules then the benefits diminish. So it is really not that much faster." [ID 6]*

> *"Why would you get a WMC faster? Have you listened the comments of Reponen [construction company] from the house fair project in Kivistö? Did it turn up faster? […] The concrete frame will rise a floor/week when it is properly designed and made. This is….the argument how WMC is sold, you probably notice from my rhetoric, but I'm not nearly from the worst side of the industry and I have some passion for thinking this subject really." [ID 2]*

Finally, the respondents were asked to give their views on market share development of WMC toward 2030. Some respondents gave their predictions in percentages and others in a more descriptive manner. In some cases, when the current market share of WMC was asked, the given response was "in the range of 5–10%". In hindsight, the more precise expression should have been at around 5%. The maximum market share prediction was 20% of new construction or that the building stock would double in 2030 compared to the current situation. Conversely, the lowest estimates were that the share would be the same as now or that there would be only incremental growth going forward. It is noteworthy that none of the respondents saw that market share would decrease. Some of the answers expressed were as follows:

> *"Not more than 20% of MC production volume. I predict that it will fluctuate in the range of 5–10%." [ID 2]*

> *"Certainly it will not more than double if now there is, let's say 60 buildings now, so 120 at maximum, but that would already mean an enormous growth given this period which we have lived through." [ID 3]*

> *"What is its share now of the yearly production? A few percent? […] I think it will double from the current, but it will not increase more." [ID 6]*

"Very minor. […] 12 years so I would believe that it will not grow very much […] It will stay the same, because of its expensiveness. I don't believe it will grow much i.e. that kind of trend will not come." [ID 10]

Additionally, some respondents further elaborated their insights on changes that should take place for wider adoption of WMC in Finland. In short, further development of processes and especially cost-competitiveness could be identified as the main factors as these examples show:

"Pretty impossible to evaluate. Let's say that it will probably become more common and the market share will expand. Figures I cannot say, but it is very much dependent on what is the advantage in it. Ok, from a life-cycle view its carbon footprint is positive and advantageous in that way and it is a natural material, but it should also have a clear cost-advantage which would be a driver that would boost it forward and currently that is not visible at least in my opinion." [ID 1]

"It is now a few percent? I have the idea that it was around 5% […] It would be nice to see that figure [5–10%] in ten years, but I will still say that below 10%. It does not really…well ok, if large construction companies will adopt the process so that it would become cost-competitive, because now it is not competitive regarding the price. This is why concrete is used." [ID 4]

6 Discussion

6.1 Reflections on the framework

With reference to Porter's five forces framework in the background, it is relevant to draw concise conclusions from literature and interviews. The threat of new entrants in residential MC can be deemed as low. This also applies globally as companies tend to operate in domestic markets as many political, economic and other risks add a layer of complexity to the already intricate business environment (see e.g., Gunhan & Arditi, 2005). However, very large global players could disrupt the Finnish market by offering e.g. truly low-cost options compared to the existing price levels of a particular region. More competition could potentially boost the innovation rate within the industry. Another option is a partnership of two or more companies with either a similar or different business background. An example of the latter is a concept called BoKlok, a collaboration between a construction company (Skanska AB) and IKEA, which uses wooden modular elements in attempt to create reasonably priced apartments. Although the focus is mainly in 2-story urban buildings, this concept is being adopted for a 5-story WMC project in Finland. By combining the benefits of off-site production with the assembly speed of modular units, cost-reductions compared to the conventional methods could be theoretically achieved without compromising quality. Arguably, quality could be further improved as modules are built in a controlled environment with precision. Furthermore, competition from other industries cannot be overlooked. For example, Alphabet's sister company Sidewalk Labs LLC has a concept of creating over 3,000 apartments using wooden-based modular units and applying technologies for a smart city in Toronto, which has gained media attention (e.g., Bozikovic, 2017; Marotta & Wong, 2018), However, the company's use of data and privacy-related concerns in the concept has also raised critiques (Fry, 2018). Another example of a potential disruptor is a Silicon Valley based start-up Katerra Inc., which aims for efficiency and cost advantages in the building process through vertical integration.

Although the aforementioned companies act in Canada and the U.S., there are companies in Finland utilizing vertical integration e.g. Lehto Oyj, Fira Oy and Sisco Oy. The former two manufacture e.g. their own bathroom modules from concrete and the latter assembles wooden apartment modules from LVL in its own factory. To the best of the writer's

knowledge, this cannot be viewed as a customary way of operating, at least as an in-house procedure.

In the context of WMC in Finland from a pure material perspective, the bargaining power of suppliers, i.e. domestic EWP suppliers, is rather high compared to concrete suppliers. For instance, there are two domestic LVL producers (Stora Enso Oyj and Metsä Wood) and a few domestic manufacturers of CLT (e.g., CLT-Plant Oy, Celt Oy & CLT Finland Oy). If compared to the concrete manufacturing side, at least 30 companies could be named, where the net sales range from €6.1 million to €226.3 million in 2017 from a total of €1.157 million (RT/Betoniteollisuus, 2018). According to a few respondents, the competition from the wood products' side was not seen as efficient or severe. Foreign competitors have also become present with either signing a licensing agreement or with exports in the Finnish WMC market thus increasing the supply. For example, a Finnish company (Suomen Puukerrostalot Oy) signed an exclusive rights contract with a Swedish company Lindbäcks Bygg AB, which is Europe's largest industrial wooden modular manufacturer (Suomen Puukerrostalot Oy, n.d.). The yearly production volume of Lindbäcks is 2,500 units, which is more than the total existing WMC building stock in Finland. In addition, the agreement enables access of the expertise, which at least on paper should provide faster progress in the beginning. (Suomen Puukerrostalot Oy, n.d.) Therefore, there is potential for benefitting from gaining knowledge through partnerships and offsetting the early stage problems that would arise.

The threat of substitute products or services could be in this connection modular solutions. Merely e.g. wood cannot be identified as a particular threat by the industry as the material is familiar and already been used in many other situations either by itself or in tandem with other materials. Rather, modular solutions could possess a threat to the current operating logic that relies heavily on prefabricated concrete elements or in-situ concrete casting. Although admittedly, the latter method is nowadays rarely used in residential MC projects in Finland. Although the drawbacks of modular solutions are the high initial costs, possible logistical challenges and some limitations in customization or modifiability, its use could still be justified in many situations. However, incorporating modular solution needs a change in the BAU operating logic and attempt to setting aside possible cognitive biases and attitudes.

There has to be done a distinction when analyzing the bargaining power of customers. Customers can be regarded as end-users i.e. consumers or various organizations and (institutional) investors. Investors possess a relatively large bargaining power in general, but individual consumers do not. Consumers as a vast group, if trends, styles or incentives change, have potentially bargaining power. Investors on the other demand e.g. LEED or BREEAM certificates in their real estate investments, which also pushes the companies for responding to demand and innovate. However, institutions and other investor groups involved in e.g. owning and renting apartments could potentially have a significant role in creating demand on the residential side for WMC as well. To take it further, special investment funds possessing real-estate investments or funds focusing on environmental, social and governance (ESG) criteria investments could potentially start to demand WMCs to their portfolio if this investment class suits their strategy. In theory, global investors and domestic pension funds could be also potential clients in the industry to name a few. Although the probability of such actions remains unanswered in this study, it could be a possible interest for further research.

The underlying offering is in essence quite similar in the more commonplace building methods when assessing the fifth force i.e. jockeying for position among current competitors. Naturally, consumers are offered more personal interior design options and appearance and functionality factors can be influenced with architectural ingenuity. However, as the mainstream offering and competitive environment is rather similar, positioning in the expertise of WMC could give potentially competitive advantage. The role and actions of municipalities can affect the market, especially in situations where zoning requires a WMC, which "knocks-out" many other competitors who are not willing or capable of expanding from their usual way of operating. As noted by Hurmekoski et al. (2018) providing support or favoring a single material should be approached with some caution to inhibit e.g. negative publicity and counter-lobbying. Evidence of counter-lobbying is prevalent when inspecting the Supreme Administrative Court of Finland’s ruling KHO:2015:56, where the court ruled for the municipalities right to choose the frame material of a building when zoning. Arguably, a polluter-pays principle would be potentially more objective and result in a more level playing field. Additionally, this would potentially push innovation and investments in areas where these procedures would affect the most.

6.2 Some implications

This study provides more insights toward the viewpoints in Finnish construction industry stakeholders affecting the current and future development of the residential MC industry in general and aspects concerning WMC. There could be found both similarities and discrepancies when compared to previous literature and naturally within the interviewees as well.

Overall, the experts saw that there is still work needed to enhancing productivity in the industry. However, according to the few with whom the issue was briefly discussed, a project alliance model was not regarded as a silver bullet for productivity in the MC industry. This notion slightly diverges from the implication of Hurmekoski et al. (2015b), where the use of an alliance project model was considered. However, the importance of cooperation of stakeholders was discussed in this study, a criterion found important in the study of Matinaro and Liu (2016). Yet, there is room for studying more on the possibilities of an alliance project model for gaining e.g. cooperation and productivity in the residential construction side. The possibilities of an alliance model were not included in the original series of questions and was only asked as a follow-up question among a few. Therefore, it is important not to make vast generalizations. According to the few experts, the problematics in the alliance model for the MC industry is that larger companies may have the upper hand in possible disputes, as there is not a court where to appeal as there is in other contracting models. Thus, it may be unbeneficial for small and medium size actors. Other views were that in the case of property development, it would not bring drastic changes or improvements to the current operating logic and the possible benefits would remain very limited. If an alliance model would not bring meaningful improvements in MC productivity, then investigating the possibilities of modular solutions could be given more thorough attention. In theory, this could potentially simplify the building phase and bridge the gap between information and smooth transitions as the need for 50 or more subcontractors in a site is not necessarily the most efficient way of operating from a productivity perspective as it might minimize different kind of "waste" in the process.

Additionally, adopting digital solutions were seen to increase productivity. Although virtual reality (VR), augmented reality (AR) or mixed-reality (MR) solutions were not mentioned verbatim, the possible benefits could be further inspected in both B2B and B2C markets or in a company's internal design process. These solutions could be

therefore studied in future e.g. in tandem with BIM solutions and WMC. To add, many experts saw that cooperation within the realm of WMC was seen as a possibility and some had projects already in the pipeline for WMC. However, the industry seems to keep underinvesting in general (e.g., Bughin et al., 2017). As discussed by Matinaro and Liu (2015), it would seem that rethinking organizational structures and improving leadership skills are especially needed in the Finnish context for enhancing productivity. These notions raise further questions on the stability of the perpetual cost-cutting mindset. Would it not be better to enhance productivity and profitability with other ways? Are the owners, shareholders and board of directors satisfied with the current financial or non-financial key performance indicators (KPIs) or are they accustomed the notion that it is a relatively "low-margin" industry? In the short-term, deviating from BAU practices would probably raise costs, but in the mid to long-term it could bear fruit. Although acknowledging that the devil is in the detail, these issues remain rather puzzling.

Potential disruptors like Katerra Inc. and Sidewalk Labs LLC could generate more innovation benefitting the whole industry. As they are originally technology-based and without the long history of habits and a BAU mindset, they could find surprising methods for adopting solutions.

Due to the strong role of municipalities and their influence on zoning, standardization was seen difficult to be fully utilized. Some experts mentioned that they have their own solutions, which they attempt to implement and do modifications depending on the zoned area. In addition, delays and complaints regarding a certain zone are inherent, which also affect the productivity and lead-times of a project. Therefore, the cooperation between municipalities is valued and communication is preferred.

The higher cost of WMC was often mentioned when hindrances were discussed. This is consistent with what has been found in previous studies (e.g., Gosselin et al., 2017; Jones et al., 2016; Riala & Ilola 2014). However, the building speed was not seen relevant enough when considering the whole construction process. In instances where the potential of modular systems in WMC was either mentioned by the interviewer, especially the potential benefits gained with speed, one noted that in practice this has not been achieved. In addition, the mandatory sprinkler systems are mentioned as a cost-adding factor. In

contrast, however, one respondent noted that sprinklers do not account for a large amount of cost in the grand scheme of things.

This raises further questions on what would be convincing for increasing modular WMC solution if the speed was not. Intuitively, investors would appreciate the speed as tenants could move in quicker thus generating cash flow earlier. Possibly, the currently perceived risks outweigh the potential benefits, from which this behavioral inclination can be grounded in Prospect theory (Kahneman & Tversky, 1979). Other psychological factors such as loss aversion, anchoring and status quo bias in decision-making (Samuelson & Zeckhauser, 1988) are at play whenever humans are involved. Thus, decision making under uncertainty may be one hindrance among others.

Political decisions made in the future may affect price development between materials in addition to inherent price fluctuations in the market. For instance, decisions for a carbon-tax, and depending on the rate, could have an effect on the market with a varying degree. In January 2019, The Wall Street Journal published Climate Leadership Council's statement of economists' policy recommendations on carbon dividends (Economists' Statement on Carbon Dividends, 2019). In short, this bipartisan agreement for climate change provides five recommendations, which original 45 co-signatories include 27 Nobel Laureate Economists, 4 former chairs of the Federal Reserve, former Chairs of the Council of Economic Advisers and former Secretaries of the U.S. Department of Treasury[2].

Although the aforementioned statement considers the case of the U.S., the potential for carbon dividends in the Finnish or European context could be an interesting topic for further research. Furthermore, the viewpoints of some experts in this study regarding financial steering in Figure 2.1 were inclined toward that possible financial steering should be directed to the end-user rather than directly to the companies. This was especially noted in instances where the view was based on the assumption that costs will increase. A carbon dividend of sorts to the end-user could be further investigated in residential construction. As demand is a strong driver for the construction companies, a reward system for end-users would potentially engage consumers collectively demanding

[2] The full list of signatories is available at: https://www.clcouncil.org/economists-statement/

more energy efficient buildings or buildings attributing to more environmentally sustainable material choices. Arguably, some of the simplest forms of rewards could be regarding subsidies on price or deduction of interest in mortgages. In Finland, the deduction of interest in mortgages has been declining annually from 2011 of 100% to 25% in 2019 (Taxpayers Association of Finland, 2018). Thus, this type of incentive would not be unusual and could be arguably practicable without added bureaucracy. However, with the current low interest rate environment in Europe, the benefits would not necessarily be substantial enough at this time.

This study supports the notion of Hurmekoski et al. (2015b) that companies acting in the WMC should collaborate and share responsibilities with other stakeholders. This occurred in instances where the lack of standardization and the limitations in the supply of WMC were mentioned. Thus, the standardization of WMC was not deemed complete enough even though this need has been recognized much earlier (Ijäs, 2014; Karjalainen, 2002) and still very recently (Hurmekoski et al., 2018; Toppinen, 2018a). Although actors in the wood products industries have provided instruction manuals and technical brochures (e.g., www.clt.info and BIM Toolbox by Stora Enso) and other digital open-source platforms for different stakeholders (e.g., Plan B from Metsä Wood) and the RunkoPES solution, these were not seen sufficient. One problem mentioned was also that there are instances where no one has a definite correct answer for some very particular solutions, which is a risk-adding factor. Therefore, standardization of especially minor details is still needed.

6.3 Limitations

Naturally, there are limitations that need to be addressed in this research. First, as the interviews were held in Finnish, there are verbal intricacies and nuances in the Finnish language that are difficult or impossible to translate into English. For instance, all interviewees spoke colloquial Finnish and translating into written English might affect the presented quotes and inhibit portraying the underlying atmosphere. For example, in instances where humor was present, it is not easily or at all perceivable in the written form. As Poland (2003, p. 273) points out, there are *"many aspects of interpersonal interaction and nonverbal communication are not captured in audiotape records, so that the audiotape itself is not strictly a verbatim record of the interview."* Additionally,

decisions of either incorporating or omitting quotes was done subjectively and possibility for human error is always present. Thus, the final representation would vary depending on the individual. In attempt to stay within the guidelines of the study, omitting quotes was necessary. Nevertheless, pursuing to present the relevant data was strived for.

Secondly, the geographical concentration is evident, as all the interviews were located at the interviewee's office premises in the Greater Helsinki area. That is, the respondents were possibly reflecting their views in this particular area, although more views that are general were naturally expressed given their expertise. It is also possible that if conducted in different areas of Finland to experts with a similar background, different views could occur. Furthermore, all of the respondents had a higher educational background in engineering, which corresponds to the notion of homogenous background in the Finnish construction industry (Matinaro & Liu, 2016). However, this was partly expected given the experts roles where their educational background is relevant or in many cases even necessary.

Finally, the sample size is relatively small due to the nature and available resources of the study. In addition, results reported in Figure 5.1 and Table 5.1 are by nature descriptive. They merely aid in presenting the data in a visual form. With the aforementioned limitations in mind, it is not advisable to make any generalizations of these results.

7 Conclusions

This study aimed to obtain the viewpoints of construction company managers and executives who either act or are closely involved in the areas of procurement and project planning – stakeholders whose viewpoints are not overly represented in literature in the context of WMC (see also Gosselin et al., 2017; Hemström et al., 2017a). That is, perceptions regarding the productivity development of MC industry, environmental regulatory policies and the future trends in both MC and WMC industry in Finland were inquired. When coupling the results of semi-structured interviews with the existing literature, conclusions can be thus generated.

First, apart from one clearly opposite view, the majority of respondents held a similar view as the labor productivity charts in Section 2.2.1., imply. Regarding the theme of productivity, a few took comparative examples from the car manufacturing industry with the notion that the construction industry is a project-driven industry where serial production and taking liberties e.g. in design is limited. This was also seen to inhibit obtaining the benefits of learning and standardization. In addition, as municipalities have a monopoly on zoning and the requirements for various characteristics of the building are predetermined, building more repetitive designs based on the individual firm's internal solutions is not seen possible to the extent what would be feasible or preferable. If productivity development is considered low as some of the statistics point to, and there are societal ambitions for productivity improvements, giving possibilities for the use of a company's product concept was seen as a way of increasing productivity.

Although the continuous transition to prefabrication was greeted with a positive undertone, a few noted that there is still quite a lot of handiwork involved in the building process. To add, the need for skilled labor was not seen in any way decreasing even though prefabrication can at least partly mitigate the shortage. Other ways of improving productivity was simplifying design for minimizing waste and producing more with the same resources, give possibilities for building higher buildings especially in the Greater Helsinki area as proper land area is apparently becoming scarcer while migration keeps increasing. Furthermore, developing processes and continuing the efforts for better coordination in the value chain were seen as other key aspects for productivity development. For instance, developing Lean-methods even further was mentioned in

relation to project leadership and processes. Additionally, going forward with improvement of BIMs was seen necessary. In a few conversations where the current project management methods came into question under the theme of productivity, the views and possibilities of implementing a project alliance model in MC was discussed. Although the project alliance model has gained positive remarks in infrastructure and public construction, it was not regarded as a silver bullet for productivity improvement in residential MC amongst the few experts. However, as the project alliance was not directly a subset of the questionnaire, profound results cannot be generated.

Secondly, the theme concerning perceptions on current and future environmental aspects related to business operations can be interpreted as regulatory-driven. In other words, no additional metrics were mentioned to be used outside from the ones mandated by legislation. One viewpoint for this was that current regulations already demand extensive documentation, which covers environmental issues as well. Thus, it was seen that the environmental policies and addressing them comes in a way 'automatically'. For instance, recycling was approached with a neutral or positive tone, as it has been a standard (legislative) process in the industry for many years. Although no particular metrics were mentioned, some were investigating the potential e.g. of Nordic Swan labelled buildings and different ways of producing energy (e.g., geothermal heat or solar energy) to the building was explored. However, questions related to energy efficiency of projects were emphasized when considering this theme, which is admittedly an area of much needed attention in climate change mitigation activities. This study revealed similar notions of Giesekam et al. (2014) where carbon-related calculations were a subject of concern for a more diverse stakeholder group as well. The companies in the construction industry are at large demand-driven and e.g. investors, especially international, in the areas of real estate and office premises business demand or see more value in certificates such as LEED or BREEAM. However, consumer demand was not very visible according to the experts apart from one exception. In the contrasting answer, it was noted that consumers ask more about the environmental factors of the building and, arguably even more importantly, are willing to pay for it.

Overall, most of the experts were well informed about future environmental plans at a general level at least. Moreover, four of the experts said they had seen Figure 2.1

previously and had varying degrees of familiarity with the roadmap presented in Bionova (2017).

Concerns of the regulatory role in Figure 2.1 raised the most questions. For instance, more cooperation with regulators instead of top-down orders was seen desirable and some discussed the role of lobbyists and their input toward the report and their overall influence in the industry in general. As cost competitiveness is inherently existent in the industry, the viewpoints on the financial steering were asked. Arguably, one could intuitively think that the companies would want direct financial compensation for speeding up the implementation of the roadmap. However, this was not the case. A few interviewees mentioned that it would simply raise apartment prices. To add, some mentioned that the possible financial incentives should be allocated to the consumers rather than to the companies. Some other respondents were more in favor for municipalities or regulators making concessions in building regulations or demands in zoning. Although the possibility of tax-deductions and decreasing building license prices were pondered, the aspects concerning regulatory relief was seen as a preferable direction. Not requiring e.g. a bomb-shelter in each building was one of the mentioned concrete examples of regulatory relieving, which would result in lower production costs and subsequently reflect to the selling price or at least balance the perceived higher cost in implementing the roadmap.

Thirdly, the viewpoint on the future toward 2030 generated various responses. The most frequently mentioned trend was prefabrication or more specifically, transitioning and utilizing the possibilities of prefabrication in different solutions further. Finding ways of utilizing the effects of robotics and component solutions were also mentioned by a few when further elaborating the possibilities of prefabrication. In addition, increasing the rate of digital solutions was seen coming to the industry. One could argue, and according to some responses somewhat belatedly if compared to some other industries, however, transformation in the industry's operating logic was seen either inevitable or probable at the very least. Two experts even mentioned WMC as a trend. Other trends toward 2030 included the need of further development of BIMs, possible emergence of smart materials, which could present e.g. visually the status of dryness or other wanted attribute of the material at hand.

The trend of urbanization was seen and its effect on the Finnish housing market raised questions. Concerns on municipalities struggling with net emigration and conversely the continuum of inflow of citizens to larger cities was seen to some extent a challenging equation for consumers and their purchasing power in cities and the (decreasing) valuation of houses and apartments in towns and cities affected by negative net migration. Furthermore, it was seen to affect adversely on the demand for larger apartments, due to the higher prices in areas where the migration has accumulated.

With reference to the descriptive statistics of seven presented statements, the results showed that the most favorable statement was concerning hybrid buildings. Five out of eleven experts strongly agreed to the statement that the future of wood building is in hybrid solutions where different materials are used jointly where the benefits of each can be obtained. If added to the next choice of representing agreement, eight out of eleven, or 72%, saw this statement likely. In the study of Toppinen et al. (2018b), from where the statement is originally from, the likelihood held similarly a top position. Although not directly comparable due to the nature of both studies, these viewpoints were similar even though the background of the respondents is not. One might argue that the respondents working in wood industry or forestry would possess a preferential viewpoint compared to experts in another industry where preferring a particular material does not have direct or straightforward incentives. Nevertheless, this statement was seen most likely in both studies although taking into account the different positioning in the construction industry value chain. However, it could be interpreted that the general undertone in this study regarding hybrid buildings was that wood could be used in façades rather than as a structural material.

The aforementioned statement shared the highest place in likelihood (Toppinen et al., 2018b) with the statement concerning whether consumers will view WMC as a modern way of building (cf. statement No. 3 in this study). Interestingly, this is where the largest difference was present. The viewpoint concerning this statement produced the most disagreeing options when combined (36%), and the least choices for agreement when combined (18%). When comparing the answers to statement No. 6 in this study to the original statement of Röhr (2016) regarding prefabrication being the main operating logic in 2030, there is wider dispersion in answers adding both choices representing agreement

(60%), neutrality (30%) and disagreement (10%) as opposed to a full agreement percentage (100%) in the other study.

Even though acknowledging that this is a crude comparison without statistical relevance or comparability, the results indicate similar beliefs in statements regarding hybrid buildings, certifications schemes and effects of life cycle costing in the decision-making process. In contrast, the most notable differences in opinions regarded the statements concerning whether consumer demand for sustainable living would boost wood construction and whether consumers will view WMC as a modern way of building.

Finally, viewpoints on the role and market share of WMC toward the year 2030 were inquired. The estimates ranged from staying the same as now, i.e. no development in market share would occur, to a maximum share of 20% or non-numerical estimates of "doubling" from the current levels. Notably, none of the experts estimated that the market share of WMC would decrease from the current levels going forward to 2030. Thus, the most conservative estimations were in relation to stay at the current level. The lack of standardization and higher price could be identified as the main reasons for low adoption rate in the future. Therefore, the findings of this study found similar results with the findings of Gosselin et al. (2017) and Hurmekoski et al. (2015b). Furthermore, similar results were identified with the study of Toppinen et al. (2018a), where most experts in this study were seen not to be opposed of WMC per se, but emphasis on the need for WMC suppliers to further develop their (practical) solutions. In addition, some mentioned that they have either considered or have in the pipeline a WMC project. Tentatively, this can imply that some path dependencies in the industry has been influenced during the past decade as reference projects have increased and the governmental promotion has continued in the 2010s.

There is always room for improvement in productivity and environmental aspects. It remains to be seen how technological and digital solutions will be adopted in the construction companies and what level of benefits it may accrue. One of the central aspects in the industry is that construction companies respond heavily to demand and are cost-focused in a project-driven environment. To put it simply: when there is demand, there will be supply. The question is then more related to creating demand and whose role this eventually is, as it would seem that the companies are inclined to a reactive rather

than proactive way of operating. Therefore, there should be clear advantages in terms e.g. of costs for increasing the investment or innovation adoption rate for current actors. In addition, although the market is cyclical, the competition and the business environment is rather predictable. Conversely, the predictability potentially offers opportunities for those willing and financially able to put ideas into action. Unless there would occur large disruption or governmental steering, only incremental process or product level changes can be expected.

As a final conclusion, this study indicates that the most likely avenue for increasing wood utilization in residential MC is in hybrid buildings. In the case of WMC in Finland, developing off-site modular solutions even further to fully achieve the benefits of construction speed, cost reduction, quality and productivity would potentially be the most prominent way in the future. However, developing and implementing new methods is not entirely on the hands of the construction companies, suppliers or other possible competitors in search of disrupting the residential MC market. Other stakeholders such as municipalities should act as an enabler rather than a hindrance if e.g. higher productivity levels are desired. Moreover, if more transformational changes are strived for, cooperation between stakeholders and industry's leadership skills should be valued and improved constantly when pursuing methods for continuous improvement within the construction business.

References

Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes*, *50*(2), 179–211. http://doi.org/10.1016/0749-5978(91)90020-T

Anderson, C. (2010). Presenting and Evaluating Qualitative Research. *American Journal of Pharmaceutical Education*, *74*(8), 141. Retrieved from http://www.ajpe.org/doi/pdf/10.5688/aj7408141

Bernard, H.R. (2006). *Research Methods in Anthropology: Qualitative and Quantitative Approaches* (4th ed.). Oxford, UK: AltaMira Press.

Bioeconomy. (2014). *The Finnish Bioeconomy Strategy*. Retrieved from https://biotalous.fi/wp-content/uploads/2014/08/The_Finnish_Bioeconomy_Strategy_110620141.pdf

Bionova. (2017). *Tiekartta rakennuksen elinkaaren hiilijalanjäljen huomioimiseksi rakentamisen ohjauksessa*. Retrieved from http://www.ym.fi/download/noname/%7B4B3172BC-4F20-43AB-AA62-A09DA890AE6D%7D/129197

Bozikovic, A. (2017, October 17). Google's Sidewalk Labs signs deal for 'smart city' makeover of Toronto's waterfront - *The Globe and Mail*. Retrieved February 22, 2019, from https://www.theglobeandmail.com/news/toronto/google-sidewalk-toronto-waterfront/article36612387/

Bugge, M., Hansen, T., & Klitkou, A. (2016). What Is the Bioeconomy? A Review of the Literature. *Sustainability, 8(7),* 691. http://doi.org/10.3390/su8070691

Bughin, J., Manyika, J., Woetzel, J., Mattern, F. M., Chui, S., Lund, A., … Pinkus, G. (2017). *Reinventing construction: a route to higher productivity*. Retrieved from https://www.mckinsey.com/~/media/McKinsey/Industries/Capital Projects and Infrastructure/Our Insights/Reinventing construction through a productivity revolution/MGI-Reinventing-construction-A-route-to-higher-productivity-Full-report.ashx

Bygballe, L. E., & Ingemansson, M. (2014). The logic of innovation in construction. *Industrial Marketing Management*, *43*(3), 512–524. https://doi.org/10.1016/j.indmarman.2013.12.019

Dodd, N., Cordella, M., Traverso, M., & Donatello, S. (2017). *Level(s) – A common EU framework of core sustainability indicators for office and residential buildings: Parts 1 and 2.* Luxembourg: Publications Office of the European Union

Eastman, C. M., & Sacks, R. (2008). Relative productivity in the AEC industries in the United States for on-site and off-site activities. *Journal of Construction Engineering and Management, 134 (7)*, 517-526. https://doi.org/10.1061/(ASCE)0733-9364(2008)134:7(517)

EC. (2010). *Europe 2020. A strategy for smart, sustainable and inclusive growth.* COM(2010) 2020. Brussels: European Commission.

EC. (2011). *Roadmap to Resource Efficient Europe*. COM(2011) 571. Brussels: European Commission.

EC. (2012). *Innovating for Sustainable Growth: A Bioeconomy for Europe*. COM(2012) 60 Final. Brussels: European Commission.

EC. (2014). *A policy framework for climate and energy in the period from 2020 to 2030*. COM(2014) 15 final. Brussels: European Commission.

EC. (2015). *Closing the loop - An EU action plan for the Circular Economy. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions*. COM(2015) 614 final. Brussels: European Commission.

Economists' Statement on Carbon Dividends. (2019, January 16). *The Wall Street Journal,* Retrieved from https://www.wsj.com

EU. (2007). *A lead market initiative for Europe.* COM(2007) 860 Final. Brussels: Commission of the European Communities

Fry, E. (2018, October 17). How Sidewalk Labs Plans to Transform Toronto-And Deal With Critics. *Fortune.* Retrieved from http://fortune.com/2018/10/17/alphabet-google-sidewalk-labs-toronto-canada-2/

Gagnon, S., Pirvu, C., & FPInnovations (Institute). (2011). *CLT handbook: Cross-laminated timber*. Québec: FPInnovations.

Giesekam, J., Barrett, J., Taylor, P., & Owen, A. (2014). The greenhouse gas emissions and mitigation options for materials used in UK construction. *Energy and Buildings*, *78*, 202–214. http://doi.org/10.1016/J.ENBUILD.2014.04.035

Gosselin, A., Blanchet, P., Lehoux, N., & Cimon, Y. (2017). Main Motivations and Barriers for Using Wood in Multi-Story and Non-Residential Construction Projects. *BioResources, 12*(1), 546-570. doi:10.15376/biores.12.1.546-570

Grundy, T. (2006). Rethinking and reinventing Michael Porter's five forces model. *Strategic Change*, *15*(5), 213–229. http://doi.org/10.1002/jsc.764

Gunhan, S., & Arditi, D. (2005). International Expansion Decision for Construction Companies. *Journal of Construction Engineering and Management*, *131*(8), 928–937. http://doi.org/10.1061/(ASCE)0733-9364(2005)131:8(928)

Gustavsson, L., & Sathre, R. (2011). Energy and CO2 analysis of wood substitution in construction. *Climatic Change*, *105*(1–2), 129–153. http://doi.org/10.1007/s10584-010-9876-8

Haapio, A. (2013). *Puurakentamisen tulevaisuuden näkymät. Haastattelututkimus [Future trends of wood construction. Interviews]*. Espoo: VTT Technology 141. Retrieved from http://www.vtt.fi/inf/pdf/technology/2013/T141.pdf

Hafner, A., & Schäfer, S. (2017). Comparative LCA study of different timber and mineral buildings and calculation method for substitution factors on building level. *Journal of Cleaner Production*, *167*, 630–642. http://doi.org/10.1016/j.jclepro.2017.08.203

Harvey, W. S. (2010). Methodological Approaches for Interviewing Elites. *Geography Compass*, *4*(3), 193–205. http://doi.org/10.1111/j.1749-8198.2009.00313.x

Hemström, K., Gustavsson, L., & Mahapatra, K. (2017a). The sociotechnical regime and Swedish contractor perceptions of structural frames. *Construction Management and Economics*, *35*(4), 184–195. http://doi.org/10.1080/01446193.2016.1245428

Hemström, K., Mahapatra, K., & Gustavsson, L. (2011). Perceptions, attitudes and interest of Swedish architects towards the use of wood frames in multi-storey buildings. *Resources, Conservation and Recycling*, *55*(11), 1013–1021. http://doi.org/10.1016/j.resconrec.2011.05.012

Hemström, K., Mahapatra, K., & Gustavsson, L. (2017b). Architects' perception of the innovativeness of the Swedish construction industry. *Construction Innovation*, *17*(2), 244–260. https://doi.org/10.1108/CI-06-2015-0038

Herczeg, M., McKinnon, D., Milios, L., Bakas, I., Klaassens, E., Svatikova, K., & Widerberg, O. (2014). *Resource efficiency in the building sector. Final report.* Rotterdam: Ecorys Nederland BV. Retrieved from http://ec.europa.eu/environment/eussd/pdf/Resource efficiency in the building sector.pdf

Herrala, O. (2018, April 1). Rakentamisen surkealle tuottavuudelle selitys – Professori: ”Työajasta vain 30 prosenttia tuottavaan työhön". *Kauppalehti*. Retrieved from https://www.kauppalehti.fi/uutiset/rakentamisen-surkealle-tuottavuudelle-selitys-professori-tyoajasta-vain-30-prosenttia-tuottavaan-tyohon/5e062e27-4596-3b91-8a2d-93a96c63b6d0

Hertz, R. & Imber, J. B. (1995). *Studying elites using qualitative methods*. Thousand Oaks, CA: Sage.

Hirsjärvi, S., Hurme, H. (2001). *Tutkimushaastattelu: teemahaastattelun teoria ja käytäntö.* Helsinki: University Press. (Original work published 2000)

Hurmekoski, E. (2016). Long-term outlook for wood construction in Europe. *Dissertationes Forestales*, (211), 57. http://doi.org/10.14214/df.211

Hurmekoski, E., Hetemäki, L., & Linden, M. (2015a). Factors affecting sawnwood consumption in Europe. *Forest Policy and Economics*, *50*, 236–248. http://doi.org/10.1016/j.forpol.2014.07.008

Hurmekoski, E., Jonsson, R., & Nord, T. (2015b). Context, drivers, and future potential for wood-frame multi-story construction in Europe. *Technological Forecasting and Social Change*, *99*, 181–196. http://doi.org/10.1016/j.techfore.2015.07.002

Hurmekoski, E., Pykäläinen, J., & Hetemäki, L. (2018). Long-term targets for green building: Explorative Delphi backcasting study on wood-frame multi-story construction in Finland. *Journal of Cleaner Production*, *172*, 3644–3654. http://doi.org/10.1016/J.JCLEPRO.2017.08.031

Höök, M., & Stehn, L. (2008). Lean principles in industrialized housing production: the need for a cultural change. *Lean Construction Journal*, 20–33.

Ibn-Mohammed, T., Greenough, R., Taylor, S., Ozawa-Meida, L., & Acquaye, A. (2013). Operational vs. embodied emissions in buildings—A review of current trends. *Energy and Buildings*, *66*, 232–245. http://doi.org/10.1016/j.enbuild.2013.07.026

Ijäs, V. (2013). *Puukerrostalojen rakentamisen esteet ja mahdollisuudet - Keskeisten suomalaisten rakentamis- ja kiinteistöalan sidosryhmien vertaileva asennemittaus*. Tampere University of Technology. Doctoral Thesis. Retrieved from https://tutcris.tut.fi/portal/files/2652042/ijas.pdf

IPCC. (2014). *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 1–151.

IPCC. (2018). *Global Warming of 1.5 ºC: Special report.* Switzerland: IPCC.

Johnsson, H., & Meiling, J. H. (2009). Defects in offsite construction: Timber module prefabrication. *Construction Management and Economics, 27*(7), 667-681. doi:10.1080/01446190903002797

Jones, K., Stegemann, J., Sykes, J., & Winslow, P. (2016). Adoption of unconventional approaches in construction: The case of cross-laminated timber. *Construction and Building Materials*, *125, 690-702.* https://doi.org/10.1016/j.conbuildmat.2016.08.088

Josephson, P. E., & Saukkoriipi, L. (2007). *Waste in construction projects call for a new approach*. Göteborg: Chalmers University of Technology.

Kahneman, D., & Tversky, A. (1979). Prospect Theory: An Analysis of Decision Under Risk. *Econometrica*, *47*(2), 263–291. https://doi.org/10.2307/1914185

Karjalainen, M. (2002). *Suomalainen Puukerrostalo Puurakentamisen Kehittämisen Etulinjassa*. [The Finnish multi-story timber apartment building as a pioneer in the development of timber construction] Acta Univ. Oul. C 166, 2002. Retrieved from http://jultika.oulu.fi/files/isbn9514266188.pdf

Koskenvesa, A., Koskela, L., Tolonen, T., & Sahlsted, S. (2010). Waste and labor productivity in production planning case Finnish construction industry. In *18th Annual Conference of the International Group for Lean Construction, July 14-16, Haifa, Israel* (pp. 477–486).

Kvale, S. (2007*). Doing interviews*. Thousand Oaks, CA: SAGE.

Laguarda Mallo, M. F., & Espinoza, O. (2015). Awareness, perceptions and willingness to adopt Cross-Laminated Timber by the architecture community in the United States. *Journal of Cleaner Production*, *94*, 198–210. http://doi.org/10.1016/j.jclepro.2015.01.090

Lohilahti, O., & Mölsä, S. (2017, September 4). Rakennusalalla työn tuottavuus ei ole juuri kasvanut 40 vuodessa – ongelmana on ollut vuoropuhelun puute. *Rakennuslehti*. Retrieved from https://www.rakennuslehti.fi/2017/09/rakennusalalla-tyon-tuottavuus-ei-ole-kasvanut-40-vuodessa-onko-allianssista-tai-leanista-apua/

Mahapatra, K., & Gustavsson, L. (2008). Multi-storey timber buildings: Breaking industry path dependency. *Building Research and Information*, *36*(6), 638–648. http://doi.org/10.1080/09613210802386123

Mahapatra, K., & Gustavsson, L. (2009). General Conditions for Construction of Multi-storey Wooden Buildings in Western Europe. School of Technology and Design, Reports, No. 59, Växjö, Sweden.

Marotta, S., & Wong, N. (2018, August 14). Alphabet's "Digital City" Eyes World's Biggest Timber Project. *Bloomberg*. Retrieved from https://www.bloomberg.com/news/articles/2018-08-14/alphabet-s-digital-city-eyes-world-s-biggest-timber-project

Mason, J. (2002). *Qualitative researching* (2nd ed.). London: SAGE Publications.

Matinaro, V., & Liu, Y. (2015). Virtual design and construction: innovation process and diffusion in Finnish construction business. *International Journal of Innovation and Learning*, *18*(2), 133–150. http://doi.org/10.1504/IJIL.2015.070869

Matinaro, V., & Liu, Y. (2016). Towards increased innovativeness and sustainability through organizational culture: A case study of a Finnish construction business. *Journal of Cleaner Production*, *142*(April 2018), 3184–3193. http://doi.org/10.1016/j.jclepro.2016.10.151

Maxwell, J. (2009). Chapter 7: Designing a Qualitative Study. In L. Bickman & D. J. Rog (Eds.), *The SAGE handbook of applied social research methods* (2nd ed). Los Angeles: SAGE

Ministry of Finance. (2018). *Rakentaminen 2018–2019*. Valtiovarainministeriön julkaisu 8/2018. Retrieved from http://urn.fi/URN:ISBN:978-952-251-934-4

Moghadam, M., Alwisy, A., & Al-Hussein, M. (2012). Integrated BIM/Lean Base Production Line Schedule Model for Modular Construction Manufacturing, *Proceedings of Construction Research Congress, May 2012,* 1271–1280. http://doi.org/10.1061/9780784412329.128

Moya, J. A., Pardo, N., & Mercier, A. (2010). *Energy efficiency and CO2 emissions: Prospective scenarios for the Cement industry*. Luxembourg: Publications Office of the European Union. Retrieved from https://ec.europa.eu/jrc

Naoum, S. G. (2016). Factors influencing labor productivity on construction sites: A state-of-the-art literature review and a survey. *International Journal of Productivity and Performance Management*, *65*(3), 401–421. https://doi.org/10.1108/IJPPM-03-2015-0045

Nidumolu, R., Prahalad, C. K., & Rangaswami, M. R. (2009). Why sustainability is now the key driver of innovation. *Harvard Business Review*, *87*(9), 57–64. http://doi.org/10.1109/EMR.2015.7123233

Norris, N. (1997). Error, Bias and Validity in Qualitative Research. *Educational Action Research*, *5*(1), 172–176. http://doi.org/https://doi.org/10.1080/09650799700200020

Nykänen, E., Häkkinen, T., Kiviniemi, M., Lahdenperä, P., Pulakka, S., Ruuska, A., … Tidwell, P. (2017). *Building with timber in Europe – a SWOT analysis*. Espoo: VTT Technology. Retrieved from http://www.holz.ar.tum.de/fileadmin/w00bne/www/leanWood/T297.pdf

OECD/Eurostat. (2005). *Oslo Manual: Guidelines for Collecting and Interpreting Innovation Data*, 3rd Edition, The Measurement of Scientific and Technological Activities, OECD Publishing, Paris, https://doi.org/10.1787/9789264013100-en.

Ollikainen, M. (2014). Forestry in bioeconomy – smart green growth for the humankind. *Scandinavian Journal of Forest Research*, *29*(4), 360–366. http://doi.org/10.1080/02827581.2014.926392

Official Statistics of Finland (OSF). (2017a). Buildings and free-time residences. Building stock 2016. [e-publication] http://www.stat.fi/til/rakke/2016/rakke_2016_2017-05-24_kat_002_fi.html Helsinki: Statistics Finland

Official Statistics of Finland (OSF). (2017b). Dwellings and housing conditions. Overview 2016, 2. Household- dwelling units and housing conditions 2016. Helsinki: Statistics Finland. Retrieved from http://www.stat.fi/til/asas/2016/01/asas_2016_01_2017-10-11_kat_002_en.html

Official Statistics of Finland (OSF). (2018a). Building & dwelling production. Helsinki: Statistics Finland

Official Statistics of Finland (OSF). (2018b). Productivity surveys. Helsinki: Statistics Finland

Poland, B. D. (2003). Transcription quality. In Holstein, J. A. & Gubrium, J. F. *Inside interviewing* (pp. 266-287). Thousand Oaks, CA: SAGE Publications Ltd. doi: 10.4135/9781412984492

Porter, M. E. (1979). How Competitive Forces Shape Strategy. *Harvard Business Review*, (March-April). Retrieved from https://pdfs.semanticscholar.org/c414/0a235773e2f4dd82fce90613fdff0af0bf21.pdf

PUU. (1997). Kiinteistö Oy Viikinmansio Helsinki. *PUU 3/1997*. Retrieved from http://www.puuinfo.fi/sites/default/files/content/info/puukerrostalot/puu397%20viikinmansio.pdf

Puuinfo. (2011). *Runkojärjestelmän vaikutukset puukerrostalon arkkitehtisuunnitteluun*. Retrieved from https://www.puuinfo.fi/suunnitteluohjeet/runkoj%C3%A4rjestelm%C3%A4n-vaikutukset-puukerrostalon-arkkitehtisuunnitteluun

Puuinfo. (2017). *Puun käyttö rakentamisessa kasvanut – markkinaosuuskin kääntymässä*. Retrieved from https://www.puuinfo.fi/tiedote/puun-k%C3%A4ytt%C3%B6-rakentamisessa-kasvanut-%E2%80%93-markkinaosuuskin-k%C3%A4%C3%A4ntym%C3%A4ss%C3%A4

Puuinfo. (2018). *Puurakentamisen kasvu näkyy tilastoissa*. Retrieved from https://www.puuinfo.fi/tiedote/puurakentamisen-kasvu-n%C3%A4kyy-tilastoissa

Puuinfo. (2019). *Valmistuneet puukerrostalot*. Retrived from https://www.puuinfo.fi/articles/valmistuneet-puukerrostalot

Ramesh, T., Prakash, R., & Shukla, K. K. (2010). Life cycle energy analysis of buildings: An overview. *Energy and Buildings*, *42*(10), 1592–1600. http://doi.org/10.1016/j.enbuild.2010.05.007

Riala, M., & Ilola, L. (2014). Multi-storey timber construction and bioeconomy - barriers and opportunities. *Scandinavian Journal of Forest Research*, *29*(4), 367–377. https://doi.org/10.1080/02827581.2014.926980

Ritter, M. A., Skog, K., Bergman, R. (2011). *Science Supporting the Economic and Environmental Benefits of Using Wood and Wood Products in Green Building Construction*. Madison, WI: U.S. Retrieved from https://www.fpl.fs.fed.us/documnts/fplgtr/fpl_gtr206.pdf

Rogers, E. M. (2003). *Diffusion of innovations* (5th ed.). New York: Free Press.

Roos, A., Woxblom, L., & Mccluskey, D. (2010). The Influence of Architects and Structural Engineers on Timber in Construction – Perceptions and Roles. *Silva Fennica*, *44*(5). Retrieved from http://www.metla.fi/silvafennica/full/sf44/sf445871.pdf

RT/Betoniteollisuus. (2018). Betoniteollisuuden suuruusjärjestys vuonna 2017. Retrieved from https://betoni.com/tietoa-betonista/suhdanteet-tilastot/suurimmat-valmistajat/

Ruuska, A., & Häkkinen, T. (2012). *Potential impact of wood building on GHG emissions*. Finland: VTT. Retrieved from http://www.puuinfo.fi/sites/default/files/content/tiedotteet/vtt-selvitti-puurakentamisen-yleistyminen-vahentaa-co2-paastoja-huomattavasti/potentialimpactofwoodbuildingonghgemissions1252012.pdf

Ruuska, A., & Häkkinen, T. (2016). Efficiency in the delivery of multi-story timber buildings. *Energy Procedia*, *96*, 190–201. http://doi.org/10.1016/j.egypro.2016.09.120

Röhr, R. E. A. (2016). Building together – Future of the Nordic wooden wooden multi-storey construction business. University of Helsinki. Master's thesis. Retrieved from https://helda.helsinki.fi/bitstream/handle/10138/182786/building.pdf?sequence=1

Samuelson, W., & Zeckhauser, R. (1988). Status Quo Bias in Decision Making. *Joumal of Risk and Uncertainty*, *1*, 7–59.

Sathre, R. & O'Connor, J. (2010). *A synthesis of research on wood products and greenhouse gas impacts* (2nd ed.). Vancouver, B.C.: FPInnovations. Retrieved from https://www.canfor.com/docs/why-wood/tr19-complete-pub-web.pdf

Skullestad, J. L., Bohne, R. A., & Lohne, J. (2016). High-rise Timber Buildings as a Climate Change Mitigation Measure – A Comparative LCA of Structural System Alternatives. *Energy Procedia*, *96*, 112–123. http://doi.org/10.1016/J.EGYPRO.2016.09.112

Suomen Puukerrostalot Oy. (n.d). Company web page. Retrieved from https://www.suomenpuukerrostalot.fi/ [Accessed 15 March 2019]

Sveikauskas, L., Rowe, S., Mildenberger, J., Price, J., & Young, A. (2016). Productivity Growth in Construction. *Journal of Construction Engineering and Management*, *142*(10), 4016045. http://doi.org/10.1061/(ASCE)CO.1943-7862.0001138

Sveikauskas, L., Rowe, S., Mildenberger, J., Price, J., & Young, A. (2018). Measuring productivity growth in construction. *Monthly Labor Review*. http://doi.org/10.21916/mlr.2018.1

Takano, A., Hafner, A., Linkosalmi, L., Ott, S., Hughes, M., & Winter, S. (2015). Life cycle assessment of wood construction according to the normative standards. *European Journal of Wood and Wood Products*, *73*(3), 299–312. http://doi.org/10.1007/s00107-015-0890-4

Taxpayers Association of Finland (2018). Asuntolainan korko. Retrieved from https://www.veronmaksajat.fi/Asunto-ja-auto/Asuntolainan-korot/ [Accessed 4 March 2019]

The Ministry of Employment and the Economy. (2012). *Puurakentaminen valtiovallan näkökulmasta. Puurakentamisen Road Show 2012*. Retrieved from https://www.puuinfo.fi/sites/default/files/content/info/puurakentamisen-roadshow-2012-luentoaineistot/1_PuurakentaminenValtiovallanN%C3%A4k%C3%B6kulmasta_TEM.pdf

The Ministry of the Environment. (2017). *Uusi asetus rakennusten paloturvallisuudesta vähentää tulkintoja ja yhdenmukaistaa turvallisuustasoa*. Announcement. Retrieved from http://www.ym.fi/fi-FI/Ajankohtaista/Uusi_asetus_rakennusten_paloturvallisuud(45212)

The Ministry of the Environment. (2018). *Wood Building Programme*. Retrieved from http://www.ym.fi/en-US/Land_use_and_building/Programmes_and_strategies/Wood_Building_Program/Wood_Building_Programme(47800)

The Ministry of the Environment & Puuinfo. (2018). *Suomalainen puukerrostalohankekanta – Suunnitteilla ja rakenteilla olevat suomalaisetpuukerrostalohankkeet, 11/2018*. Retrieved from https://www.puuinfo.fi/sites/default/files/Puukerrostalohankekanta%2C%20p%C3%A4ivitetty%2011-2018.pdf

The National Building Code of Finland. (2002). *Decree of the Ministry of the Environment on fire safety of buildings E1*. Retrieved from https://www.edilex.fi/data/rakentamismaaraykset/e1e.pdf

The National Building Code of Finland. (2017). *Decree of the Ministry of the Environment on fire safety of buildings E1. 848/2017.* Retrieved from https://www.ym.fi/en-US/Land_use_and_building/Legislation_and_instructions/The_National_Building_Code_of_Finland/Fire_safety

Tolppanen, J., Karjalainen, M., Lahtela, T., Viljakainen, M. (2013). *Suomalainen puukerrostalo: rakenteet, suunnittelu ja rakentaminen*. Helsinki: Opetushallitus: Puuinfo

Toppinen, A., Röhr, A., Pätäri, S., Lähtinen, K., & Toivonen, R. (2018b). The future of wooden multistory construction in the forest bioeconomy – A Delphi study from Finland and Sweden. *Journal of Forest Economics*, *31*, 3–10. http://doi.org/10.1016/j.jfe.2017.05.001

Toppinen, A., Sauru, M., Pätäri, S., Lähtinen, K., & Tuppura, A. (2018a). Internal and external factors of competitiveness shaping the future of wooden multistory construction in Finland and Sweden. *Construction Management and Economics*, 1–16. http://doi.org/10.1080/01446193.2018.1513162

UNEP & IEA. (2017). *Towards a zero-emission, efficient, and resilient buildings and construction sector. Global Status Report 2017.* 1–48. Retrieved from https://www.globalabc.org/resources/documents

UNFCCC. (1992). *United Nations Framework Convention on Climate Change (UNFCCC)*, 1–33.

UNFCCC. (2015). *Adoption of the Paris agreement - Conference of the Parties COP 21. Proposal by the President*, 32.

Van Ruijven, B. J., Van Vuuren, D. P., Boskaljon, W., Neelis, M. L., Saygin, D., & Patel, M. K. (2016). Long-term model-based projections of energy use and CO2 emissions from the global steel and cement industries. *Resources, Conservation and Recycling*, *112*, 15–36. http://doi.org/10.1016/j.resconrec.2016.04.016

Vatanen, M., Sirkka, A., Pirttinen, V., & Ahoranta, T. (2017). *Current state and future of CLT construction in Finland–Interview study 2016*. Research reports and compilations 17/2017. Rovaniemi: Lapland University of Applied Sciences

WBCSD & IEA. (2009). Cement Technology Roadmap – Carbon emission reductions up to 2050. 1–36.

WBCSD & IEA. (2018). Technology Roadmap – Low-Carbon Transition in the Cement Industry. 1–66.

Yates, M., Linegar, M., & Dujic, B. (2008). Design of an 8 storey residential tower from KLH cross laminated solid timber panels. In *10th World Conference on Timber Engineering 2008* (Vol. 4, pp. 2189–2196).

Appendices

Annex 1. Detailed explanations for building materials' fire classification (The National Building Code of Finland, 2002).

Fire classification

Buildings

Buildings are divided into three fire classes: **P1**, **P2** and **P3**.

Building elements

Load-bearing and fire-separating building elements are divided into classes depending on how they resist fire.

The requirements prescribed for building elements are described using the following symbols:

R load-bearing capacity,
E integrity,
I insulation.

The fire resistance period expressed in minutes is given after the symbols R, REI, RE, EI, E using one of the following figures: 15, 30, 45, 60, 90, 120, 180 or 240. The notation thus obtained represents the fire class of the building element.

Explanation

The fire class of a wall may be for instance REI 60 and the class of a door in the wall EI 30 or E 30. A building element, which only meets the integrity requirement E, may cause a hazard due to thermal radiation. This must be taken into consideration by establishing a safety distance to passageways in exits and to ignitable materials.

The notation may be supplemented with the symbol:

M impact resistance in case of fire.

The conformity of a building element is verified experimentally or by applying calculation methods.

The Annex of these regulations and guidelines provides information on the test methods and the basis for classification.

Building elements shall be made of such building materials that they meet the classification criteria imposed on the element for each category of use of the building.

Building materials

Classification system

Building materials are divided into classes depending on how they influence ignition of fire, spread of fire and production of smoke.

EN standards are used as test methods and for classification. A list of standards is included in the Annex 'Information for guidance'.

Available classes, supplementary additional classifications for smoke production and formation of droplets and their notation are given in Commission Decision 2000/147/EC.

The Annex 'Information for guidance' includes a table of building products generally considered as belonging to class A1 and $A1_{FL}$ without the need for testing or further approval. The table is based on Commission Decision 96/603/EC, amended 2000/605/EC.

Building materials excluding floorings

The classes for building materials are described using the following symbols: **A1**, **A2**, **B**, **C**, **D**, **E**, **F**.

Smoke generation and formation of droplets is expressed using the additional classification s and d. The classification of smoke production is **s1**, **s2**, **s3** and of formation of droplets **d0**, **d1**, **d2**.

Explanation

A1 *Products, which will not contribute at all to the fire.*
A2 *Products, which will contribute in the fire to an extremely limited extent.*
B *Products, which will contribute in the fire to a very limited extent.*
C *Products, which will contribute in the fire to a limited extent.*
D *Products, which will contribute in the fire to an acceptable extent.*
E *Products for which the reaction to fire performance is acceptable.*
F *Products for which no reaction to fire performance is determined.*

s1 *The smoke production is very limited.*
s2 *The smoke production is limited.*
s3 *The smoke production does not meet the requirements of class s1 or s2.*

d0 *No flaming droplets or particles occur.*
d1 *The flaming droplets or particles extinguish quickly.*
d2 *The formation of flaming droplets or particles does not meet the requirements of class d0 or d1.*

Classes A1 and F are always presented without any additional classifications. Class E without any additional classification implies that no flaming droplets are formed from the material. All other classes include also additional classifications, e.g. A2–s1, d0, B–s1, d0, D–s2, d2, E–d2.

Floorings

The classes for floorings are described using the following symbols: $\mathbf{A1_{FL}}$, $\mathbf{A2_{FL}}$, $\mathbf{B_{FL}}$, $\mathbf{C_{FL}}$, $\mathbf{D_{FL}}$, $\mathbf{E_{FL}}$, $\mathbf{F_{FL}}$.

Smoke production is expressed using the additional classification **s1** or **s2**.

Explanation

$\mathbf{A1_{FL}}$ *Products, which will not contribute at all to the fire.*
$\mathbf{A2_{FL}}$ *Products, which will contribute in the fire to an extremely limited extent.*
$\mathbf{B_{FL}}$ *Products, which will contribute in the fire to a very limited extent.*
$\mathbf{C_{FL}}$ *Products, which will contribute in the fire to a limited extent.*
$\mathbf{D_{FL}}$ *Products, which will contribute in the fire to an acceptable extent.*
$\mathbf{E_{FL}}$ *Products for which the reaction to fire performance is acceptable.*
$\mathbf{F_{FL}}$ *Products for which no reaction to fire performance is determined.*

s1 *The smoke production is limited.*
s2 *The smoke production does not meet the requirements of class s1.*

Use of the classification system in these regulations and guidelines

Of the classification system presented above, the following classes are used **A1**, **A2–s1**, **d0**, **B–s1**, **d0**, **C–s2**, **d1**, **D–s2**, **d2**, $\mathbf{A2_{FL}}$**–s1** and $\mathbf{D_{FL}}$**–s1**.

The additional classifications for smoke production and formation of flaming droplets used in Finland are the same for the main classes. The requirements imposed on building materials can in practice be expressed using the main classes **A1**, **A2**, **B**, **C**, **D**, $\mathbf{A2_{FL}}$ and $\mathbf{D_{FL}}$. The class designation of a building material must, however, always also include the additional classification.

Roof coverings

Roof coverings are divided into classes according to what extent they can be considered as being difficult to ignite and slowly fire spreading with respect to external fire exposure, and how they protect their substrate from ignition.

Available classes, their notation and the assessment criteria of the classes are given in Commission Decision 2001/671/EC.

Of the classification systems in the Decision, class $\mathbf{B_{ROOF}}$**(t2)** is used in these regulations and guidelines.

The Annex 'Information for guidance' includes a table of roof coverings generally considered as belonging to class $\mathbf{B_{ROOF}}$ without the need for testing or further approval. The table is based on Commission Decision 2000/553/EC.

Annex 2. The interview questionnaire.

Kysymykset:

1. Miten kuvailisitte rakentamisen tuottavuuden kehittymistä viime vuosikymmeninä?
   a) Miten tuottavuutta tulisi mielestänne mitata?

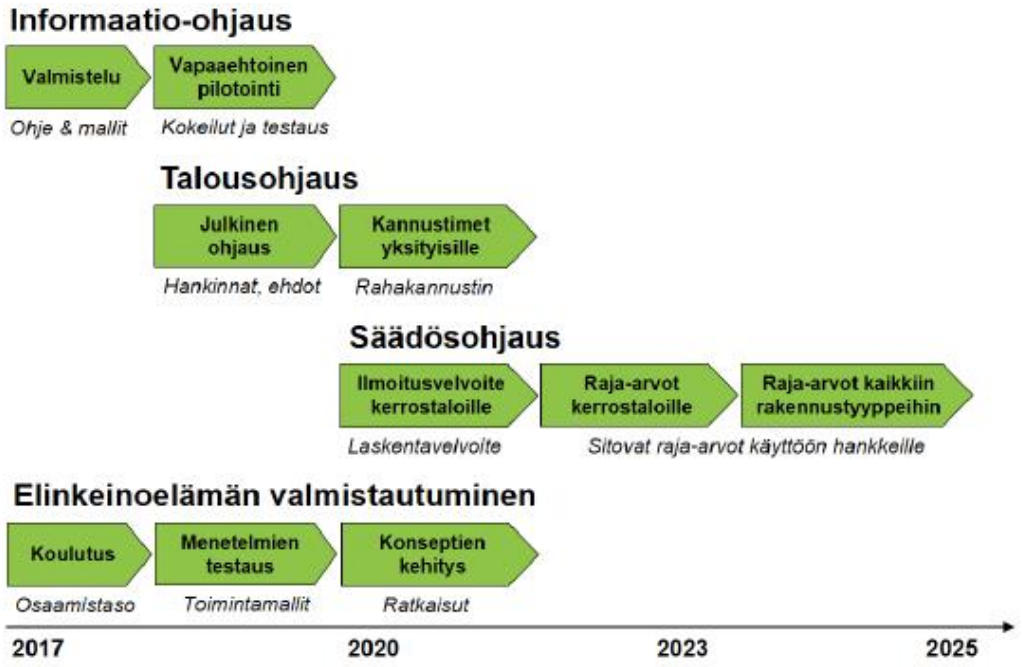
2. Minkälaisia kehitystarpeita näette tuottavuuden kasvattamiseksi?

3. Millä tavalla ympäristönäkökulmat näkyvät liiketoiminnassanne? Onko käytössänne joitain mittareita, mitä?

4. Antakaa 1–2 esimerkkiä millä keinoin edustamanne yritys on reagoinut ympäristövaatimuksiin (lainsäädännöllisiin tai markkinoiden kysynnästä liittyviin)?
   a) Kumpia perusteita yrityksesi painottaa enemmän, miksi?

5. *"Ympäristöministeriön tavoitteena on, että rakennuksen elinkaaren aikaista hiilijalanjälkeä ohjataan lainsäädännöllä 2020-luvun puoliväliin mennessä. Ympäristöministeriö on teettänyt selvityksen tiekartasta, jolla vähennetään rakentamisen ja erityisesti rakennusmateriaalien hiilijalanjälkeä sekä edistetään Suomen rakennus- ja kiinteistöalaa koskevia ilmastotavoitteita." (YM, 2017). Kysymyksen tueksi kuvaaja Bionova Oy:n (2017) selvityksestä.*

Miten arvioisitte tämän vaikuttavan teidän liiketoimintaanne?



Tiekartta ohjauksen kehityksen vaiheistuksesta. Lähde: Bionova (2017).

6. Mainitkaa 2-3 kehitystrendiä miten näette rakennusteollisuuden kehittyvän vuoteen 2030 asti? Miksi nämä ovat olennaisimpia?

7. Oheisessa ojentamassani paperissa on seitsemän (7) väittämää (aiempi tutkimus Toppinen et al. 2018). Kuinka todennäköisenä pidätte näitä asteikolla 1-5, jossa 1 = pieni todennäköisyys ja 5 = suuri todennäköisyys.

– Vuoteen 2030 mennessä rakennuksien elinkaarikustannuslaskennalla on merkittävästi enemmän vaikutusta päätöksentekoon suurimittaisissa rakennushankkeissa kuin pelkällä hankintahinnalla.

– Vuoteen 2030 mennessä kuluttajakysyntä ympäristötietoisemmalle asumiselle on merkittävästi vahvempi ajuri puukerrostalorakentamiselle kuin nyt.

– Vuoteen 2030 mennessä kuluttajat pitävät puukerrostalorakentamista nykyaikaisena tapana rakentaa.

– Tulevat rakennusalaa koskevat sertifiointisuunnitelmat ovat pienemmille yrityksille vaikea toteuttaa niihin liittyvän byrokratian johdosta.

– Puukerrostalorakentamisen tulevaisuus on nk. hybridirakennuksissa, joissa tarkoituksena on hyödyntää puuta, terästä ja betonia siellä, missä niiden käyttö tuo eniten hyötyjä.

– Vuoteen 2030 mennessä teollinen esivalmistus toimii pääasiallisena toimintatapana perinteisen työmaarakentamisen vähetessä.

– Vuoteen 2030 mennessä puun hyödyntäminen asunnon sisustusratkaisuissa kasvattaa suosiota kuluttajien keskuudessa.

8. Koetteko puukerrostalorakentamisen enemmän kilpailijana vai näettekö mahdollisuutta laajempaan yhteistyöhön? Millä alueilla yhteistyö olisi perusteltua?

9. Minkälaisena näette puukerrostalojen markkinaosuuden kehityksen Suomessa vuoteen 2030 asti?

Haastattelun lopuksi: Onko teillä muuta kommentoitavaa tai lisättävää aiheeseen liittyen?